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COVER SHEET

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INSTALLATION RESTORATION PROGRAM (IRP)

STAGE 2

CARSWELL AFB, TEXAS

RADIAN CORPORATION
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DRAFT REPORT - MAY 1991

REMEDIAL INVESTIGATION REPORT FOR THE FLIGHTLINE AREA

PREPARED FOR

HEADQUARTERS STRATEGIC AIR COMMAND
(HQ SAC/DE)
OFFUTT AIR FORCE BASE, NEBRASKA 68113-5001

UNITED STATES AIR FORCE
HUMAN SYSTEMS DIVISION (AFSC)
IRP PROGRAM OFFICE (HSD/YAQ)
BROOKS AIR FORCE BASE, TEXAS 78235-5501

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REMEDIAL INVESTIGATION FOR THE FLIGHTLINE AREA

DRAFT REPORT
FOR
CARSWELL AIR FORCE BASE, TEXAS

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PREPARED BY

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USAF CONTRACT NO. F33615-87-D-4023, DELIVERY ORDER NO. 0004, MODIFICATION 0005
CONTRACTOR CONTRACT NO. 227-005-04, DCN 91-227-005-04-07

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PREFACE

Radian Corporation is the contractor for the Installation Restoration Program (IRP) Phase II, Stage 2 investigation at Carswell AFB, Texas. The work was performed under USAF Contract No. F33615-87-D-4023, Delivery Order 0004, in two separate efforts; the first in 1987-88, and the second in 1990.

A hydrogeological investigation was conducted at several landfills, fire department training areas, and fuels handling areas to further assess and define the extent of contamination confirmed in the Stage 1 investigation at Carswell AFB. Soil gas surveys were conducted in 1988 at two locations to determine the extent of petroleum hydrocarbon vapors. Ground-water monitor wells were installed in alluvial materials to further define the limits of ground-water contamination. Soil samples were collected during drilling operations and with hand augers at selected sites and analyzed for a broad range of parameters in the initial Stage 2 effort. Water samples collected from the wells and several surface water bodies were analyzed for a wide spectrum of total metals, inorganic compounds, and organic compounds. Dissolved metals concentrations were analyzed only in the samples collected in 1990. A pumping test of the Upper Zone Aquifer was also performed in the Flightline Area in 1990. A baseline risk assessment, incorporating all analytical data, was performed, and remedial action alternatives were identified and evaluated for the Flightline Area and four sites in the East Area of the base (Sites LF01, SD13, ST14, and BSS) in the Feasibility Study.

Key Radian project personnel were:

Nelson H. Lund	IRP Contract Manager
William L. Boettner	IRP Program Manager
Lawrence N. French	Project Director/Delivery Order Manager (1987-88)
Debra L. Richmann	Project Director (1990)
Guy J. Childs	Supervising Geologist (1987-1988)
Stephen E. Fain	Supervising Geologist (1990)
Scott B. Blount	Supervising Geologist (1990)
Sandra A. Smith	Risk Assessment Task Leader
Kathleen A. Alsup	Remedial Alternatives Task Leader
Jeffery P. Young	Flightline Area FS Task Leader
Gary S. Shaw	East Area FS Task Leader
Gary L. Patton	Database Management and QA/QC Task Leader

Greg A. Hamer Senior Technical Reviewers
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Radian would like to acknowledge the cooperation of the Carswell AFB Civil Engineering Staff. In particular, Radian acknowledges the assistance of Mr. Frank Grey, Mr. Raj Sheth, and Sgt. Stanley Reinhartz.

The work reported herein was accomplished between December 1987 and July 1990. Mr. Karl W. Ratzlaff, IRP Technical Operations Branch, Human Services Division (AFSC) IRP Program Office (HSD/YAQ), was the Technical Project Manager.

Approved: [signature] for
Nelson H. Lund, P.E.
Contract Manager

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EXECUTIVE SUMMARY

A Remedial Investigation (RI) was performed by Radian under the U.S. Air Force Installation Restoration Program (IRP) to characterize environmental contamination present in the Flightline Area of Carswell AFB, Texas; the existence of which was documented in preceding IRP studies. The affected environmental media include soil, surface water, and ground water present in the surficial alluvial aquifer (Upper Zone). The main contaminants are volatile organic compounds (principally trichloroethene (TCE)) associated with waste chlorinated solvents. The RI was conducted in stages from 1988 to 1991. Radian also performed the earlier IRP Phase II Stage 1 investigation (1986); the IRP Phase I Records Search was performed by CH2M Hill (1984).

The most recent field and analytical effort was conducted in 1990 to provide additional information necessary to support a Feasibility Study (FS) of remedial alternatives applicable to the Flightline Area. The 1990 effort was limited to further characterization of four of the Flightline Area IRP sites:

- Site LF04 - Landfill 4;
- Site LF05 - Landfill 5;
- Site WP07 - Waste Burial Area; and
- Site FT09 - Fire Department Training Area 2.

The locations of these, and other Flightline Area IRP sites that are addressed in separate project reports and documents, are shown in Figure ES-1.

Four major tasks were accomplished to address the existing data gaps:

- Drilling and logging of 29 soil borings to identify the distribution of paleochannel deposits, suspected as preferential pathways for migration of contaminants in Upper Zone ground water;

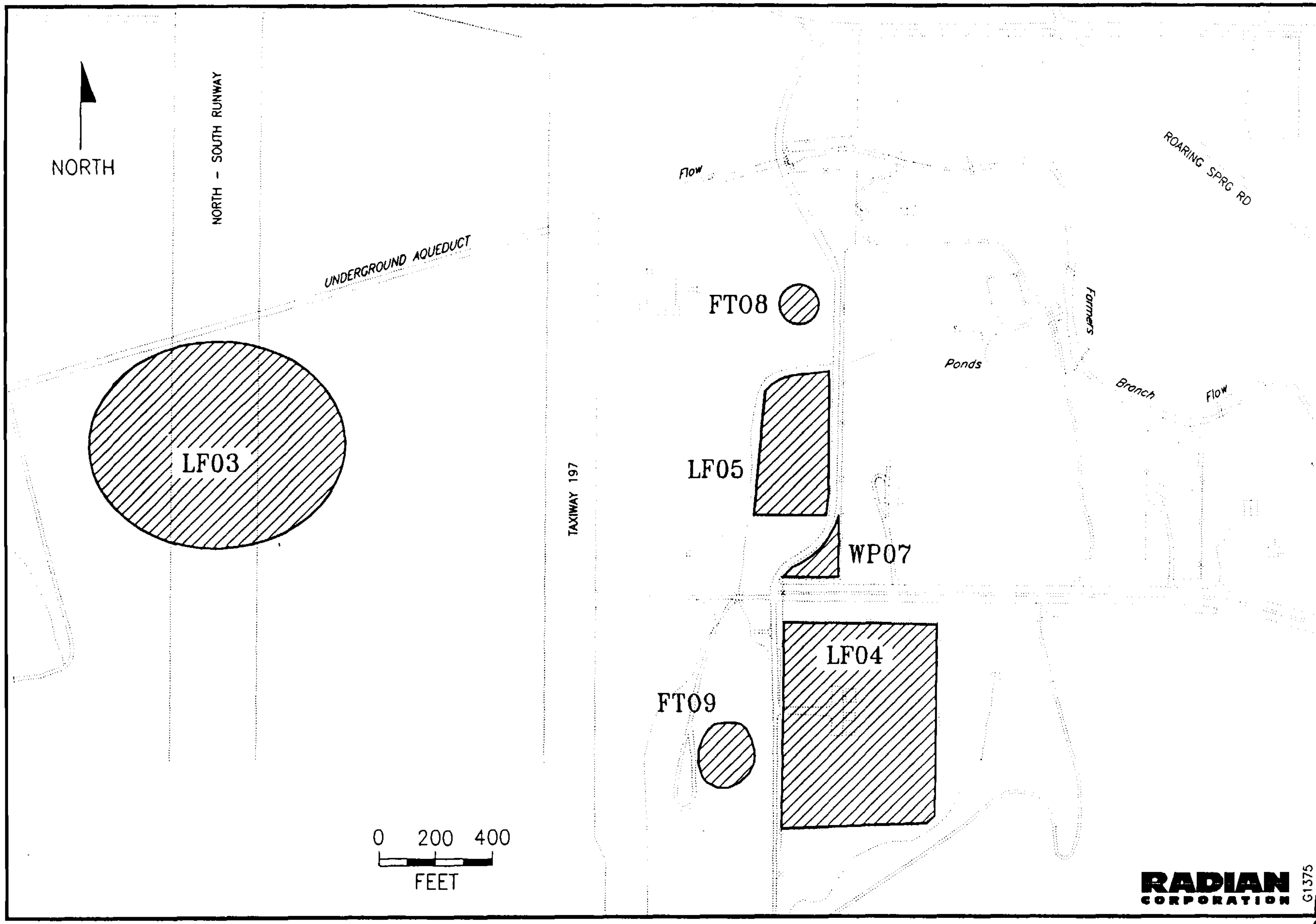

Figure ES-1. Location of Flightline Area Sites, Carswell AFB, Texas

- Installation of 10 additional monitor wells, screened to the base of the Upper Zone Aquifer to provide additional information on the areal and vertical extent of ground-water contamination and possible existence of DNAPL;

- Ground-water and surface water sampling, analysis and static water level measurement; and

- Aquifer testing to determine Upper Zone hydraulic properties in the Flightline Area.

Based on all available data, ground-water contamination appears to be limited to the shallowest water-bearing zone, known as the Upper Zone Aquifer. In the Flightline Area, as well as across Carswell AFB and the adjoining area of Air Force (AF) Plant 4, the Upper Zone consists of unconsolidated Quaternary and Recent alluvial deposits (sand, gravel, silt and clay) that contain ground water under unconfined conditions. The Upper Zone deposits in the Flightline Area vary from approximately 5 to 49 feet thick, and are underlain by low permeability limestones and shales of the Cretaceous Goodland and Walnut Formations which form a basal aquiclude. Ground water in the Upper Zone Aquifer is encountered at depths ranging from approximately 4 to 30 feet below ground level (bgl) and ground-water flow in the Flightline Area is generally toward Farmers Branch. A series of hydrogeologic cross-sections through the Flightline Area was prepared from boring logs and synoptic water level measurements. They are included in Section 3 of this report to illustrate the local subsurface conditions.

The main surface water bodies located in the Flightline Area are Farmers Branch, an unnamed tributary that flows into Farmers Branch, and two small ponds on the base golf course. Farmers Branch eventually discharges to the Trinity River, which is located along the eastern boundary of Carswell AFB. The Upper Zone ground water and surface water bodies in the Flightline Area are hydraulically related, with ground water discharging to surface water.

Trichloroethene (TCE), vinyl chloride, tetrachloroethene (PCE), and the cis- and trans- isomers of 1,2-dichloroethene (1,2-DCE) are the main contaminants detected in the ground water and surface water in the Flightline Area. Based on the concentrations and distribution of these compounds in ground water, most recently determined in the 1990 sampling and analysis program, the four former waste disposal areas (Sites LF04, LF05, WP07, and FT09) appear to be sources for some of the ground-water contaminants detected downgradient of the sites. However, all of these compounds were also detected in samples from monitor wells located hydraulically upgradient of all Carswell AFB IRP sites in the Flightline Area, indicating that additional off-base sources must also be contributing to the existing Upper Zone ground-water contamination. The occurrence of volatile organic contaminants in the Upper Zone ground water on the AF Plant 4 property, upgradient of the Flightline Area, has been documented (Hargis and Associates, 1989). The source(s) of the contamination on AF Plant 4 have thus far not been identified. However, it is likely that they are also the source(s) for the contamination detected in the upgradient Flightline Area wells, and are contributing some component to the contaminant plumes that exist downgradient of the Flightline Area IRP sites.

In conjunction with lithologic logs obtained in previous drilling efforts, logs from the new soil borings were used to delineate the thick accumulations of sand and gravel deposited in paleochannels eroded into the surface of the underlying bedrock. Figure ES-2 is the resulting sand and gravel isopach map of the Flightline Area. The areas of thickest sediment correspond well with the highest concentrations of TCE determined in 1988, suggesting that TCE (and other ground-water contaminants) may be preferentially migrating along these relatively permeable deposits in the Upper Zone. The locations of existing Carswell AFB monitor wells and wells installed in the Flightline Area by Hargis and Associates for AF Plant 4 were reviewed to determine the optimum locations for the new wells installed in 1990. Locations were selected to assess the preferential pathway hypothesis, as well as to better determine the areal extent of contamination, and the

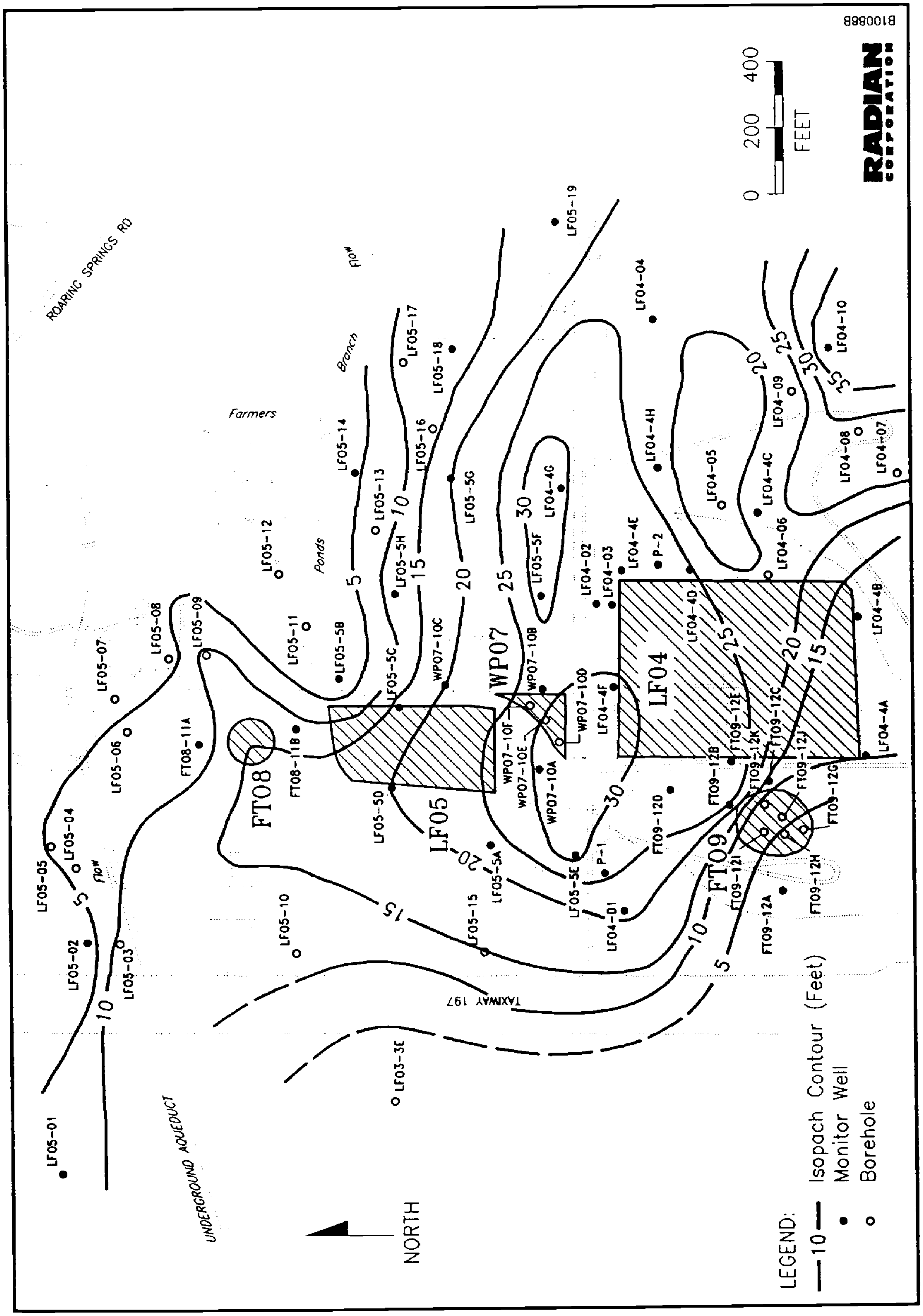

Figure ES-2. Sand and Gravel Isopach Map, Flightline Area, Carswell AFB, Texas degree of continuity of the on-site contaminant plume with documented ground-water contamination present upgradient on the adjacent AF Plant 4 property. The latter objective could not be achieved because no AF Plant 4 wells were sampled concurrently with the Carswell AFB Flightline Area wells.

The monitor wells installed in 1990 were completed to intercept the base of the Upper Zone Aquifer to determine if dense non-aqueous phase liquid contaminant (DNAPL) is present in the Flightline Area. None was detected.

The results of the 1990 sampling and analytical effort confirmed that migration of the volatile organic contaminant plumes in the Upper Zone ground water does occur preferentially within the eroded bedrock paleochannels. A secondary component of movement is in the direction of ground-water flow, generally toward Farmers Branch. The maximum downgradient limit of vinyl chloride contamination was defined by the existing well network, which was also adequate to identify multiple sporadic occurrences of PCE. However, the areal extent of TCE and total 1,2-DCE in ground water was not determined. Samples from monitor wells located along the downgradient limit of the well network contained concentrations from 1300 to 2700 ug/L, and 280 to 540 ug/L, respectively.

In contrast to findings and interpretations from previous investigations, the ground-water and surface water analytical results for samples collected in 1990 provide little evidence of a metals contamination problem. No metals were detected in concentrations above MCLs in any samples analyzed for dissolved metals and there is no apparent pattern to the few detected concentrations above MCLs in the total metals analyses. In previous sampling events, only the total metals fractions were analyzed.

A pumping well and observation well for evaluation of Upper Zone Aquifer properties were installed just north of the northeast corner of Landfill 4, near the axis of a major paleochannel. The observation well was located approximately 50 feet north of the pumping well. Seven additional monitor wells were included in the observation well network, but the measured water levels showed no response to pumping after 20 hours of pumping at the optimum rate determined in the preceding step test (approximately 20 gallons/minute). Data from the pumping test and subsequent recovery test were analyzed using the Cooper-Jacob method, and the computer Well Hydraulics Interpretation Program (WHIP™). The resulting calculated aquifer properties of transmissivity, hydraulic conductivity, and storage coefficient are summarized in Table ES-1. The values all fall within the range expected for clean sands and gravels (Freeze and Cherry, 1979).

Upper Zone ground water in the Flightline Area was determined to discharge to surface water, based on synoptic water level measurements in the monitor wells and at a staff gauge in Farmers Branch. This interpretation is supported by the similarity in ground-water and surface water contaminant distributions and concentrations in samples collected in 1990. The chemistry of surface water in the unnamed tributary to Farmers Branch suggests the water is virtually equivalent to the ground-water plume composition at the sample collection point. Volatile organic contaminants, most notably TCE, in concentrations above MCLs were detected in samples collected from both the upgradient and farthest downgradient sampling points on Farmers Branch, suggesting contributions from off-base sources, as well as the potential for off-base migration of contaminants. Estimated concentrations of TCE and total 1,2-DCE leaving the Flightline Area via Farmers Branch are 45 μg/L and 8.4 μg/L, respectively.

A baseline risk assessment, incorporating the 1990 analytical results, was performed for the Flightline Area. Site FT09 (Fire Department Training Area 2) was not included in the risk assessment because a remedial action has been selected for this site. The remedial design includes technologies that eliminate the potential for continuing releases from the site. Indicator chemicals, contaminant release,transport and fate mechanisms, and potential receptors and exposure pathways, specific to the Flightline Area were identified and evaluated. The Flightline Area was determined to pose no significant human health threat, based on evaluation of carcinogenic and noncarcinogenic (chronic) risks. Environmental (terrestrial wildlife and aquatic organisms) risks were determined to be minimal.

TABLE ES-1. SUMMARY OF UPPER ZONE AQUIFER PUMPING TEST RESULTS, FLIGHTLINE AREA, CARSWELL AFB, TEXAS (JUNE, 1990)

Well Number	Type of Test Analyses	Distance From Pumping Well (ft)	Transmissivity	Hydraulic Conductivity	Storage Coefficient (Dimensionless)
LF04-02	Drawdown	50	9771 ft^2/day	835 ft/day (2.9×10^{-1} cm/sec)	1.2×10^{-2}
	Recovery	50	8260 ft^2/day	705 ft/day (2.5×10^{-1} cm/sec)	
LF04-03	Recovery	Pumping Well	9501 ft^2/day	812 ft/day (2.9×10^{-1} cm/sec)	
		Average Values	9177 ft^2/day	784 ft/day (2.8×10^{-1} cm/sec)	1.2×10^{-2}

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Using all available information generated in the IRP, the Flightline Area (combined Sites LF04, LF05, WP07 and FT09) was evaluated using the Defense Priority Model (DPM). The Flightline Area received a total score of 19,381 and ranked second among the five Carswell AFB IRP sites/areas evaluated with the model. While the Flightline Area contamination poses no immediate human health threat, remedial action is indicated to prevent continuing contaminant release and migration. Recommendations for addressing remaining data needs for design and implementation of a remedial action are provided in Section 7. It is anticipated that all of the required data can be obtained within the detailed design phase of the selected remedial action, and no additional separate remedial investigation effort is proposed.

1.0 INTRODUCTION

1.1 Purpose of Study

The purpose of this study is to provide a sufficiently detailed description of existing environmental conditions in the Flightline Area (Sites LF04, LF05, WP07, and FT09) of Carswell AFB, Texas such that the impacts of documented ground-water contamination beneath the base can be determined and a remedial action can be designed and implemented.

Previous IRP studies documented soil and ground-water contamination, especially with trichloroethene (TCE) and chromium (Cr), in the Flightline Area. Previous investigations detected contamination of soils and ground water only in the "Upper Zone," a term used to describe the surface deposits of alluvium and fill in the Flightline Area (Hargis and Montgomery, Inc., 1983). However, the complete areal and vertical extent of the contaminant plume(s) were not defined.

Previously available evidence suggested multiple sources of the contamination, including source(s) located upgradient of all potential sources in the Flightline Area of the base. The monitoring network existing at that time was insufficient to identify and determine the relative contributions from these other sources. This report, based on additional IRP RI/FS Stage 2 field and analytical efforts performed between 5 March and 22 June 1990, addresses these data gaps and presents a summary of the current understanding of the hydrogeologic setting and Upper Zone ground-water characteristics of the Flightline Area.

Four major field tasks were designed to address existing data gaps. Soil borings were drilled and sampled to better define the distribution of basal gravels deposited in ancient river channels (paleochannels) which might serve as preferential pathways for contaminant migration. Monitor wells were installed to provide additional sampling sites to better characterize the vertical and lateral extent of ground-water contamination and potential or existing contamination sources. A comprehensive sampling of all Upper Zone wells and numerous surface water sites was conducted to determine the nature and extent of contamination present. Finally, aquifer testing was performed to define the hydraulic conditions in the Flightline Area to aid in a more accurate characterization of contaminant transport.

1.2 Site Description

Carswell AFB is located six miles west of the center of Fort Worth in Tarrant County, Texas (Figure 1-1). The focus of this investigation is on an area near the southern end of the flightline at Carswell AFB, hence the name "Flightline Area" is used to describe the location of the study area.

The Flightline Area includes six discrete sites that were identified as potential sources of contaminants in previous IRP studies (Figure 1-2). They are:

- LF03 - Landfill 3;
- LF04 - Landfill 4;
- LF05 - Landfill 5;
- WP07 - Waste Burial Area;
- FT08 - Fire Department Training Area 1; and
- FT09 - Fire Department Training Area 2.

Data obtained in the earlier IRP investigations provided no evidence that Sites LF03 and FT08 have released hazardous waste or waste constituents to the environment. Therefore, it was concluded that they do not pose an environmental or human health risk (Radian, 1989) and a Decision Summary Technical Document to Support No Further Action was prepared for each site (1990a,b). The monitor wells installed at Site FT08 were, however, included in this most recent Stage 2 ground-water sampling effort because it is likely that they are intercepting ground water that has been contaminated by one or more upgradient, potentially off-base sources. In the following subsections, Sites LF04, LF05, WP07 and FT09 are described in terms of their

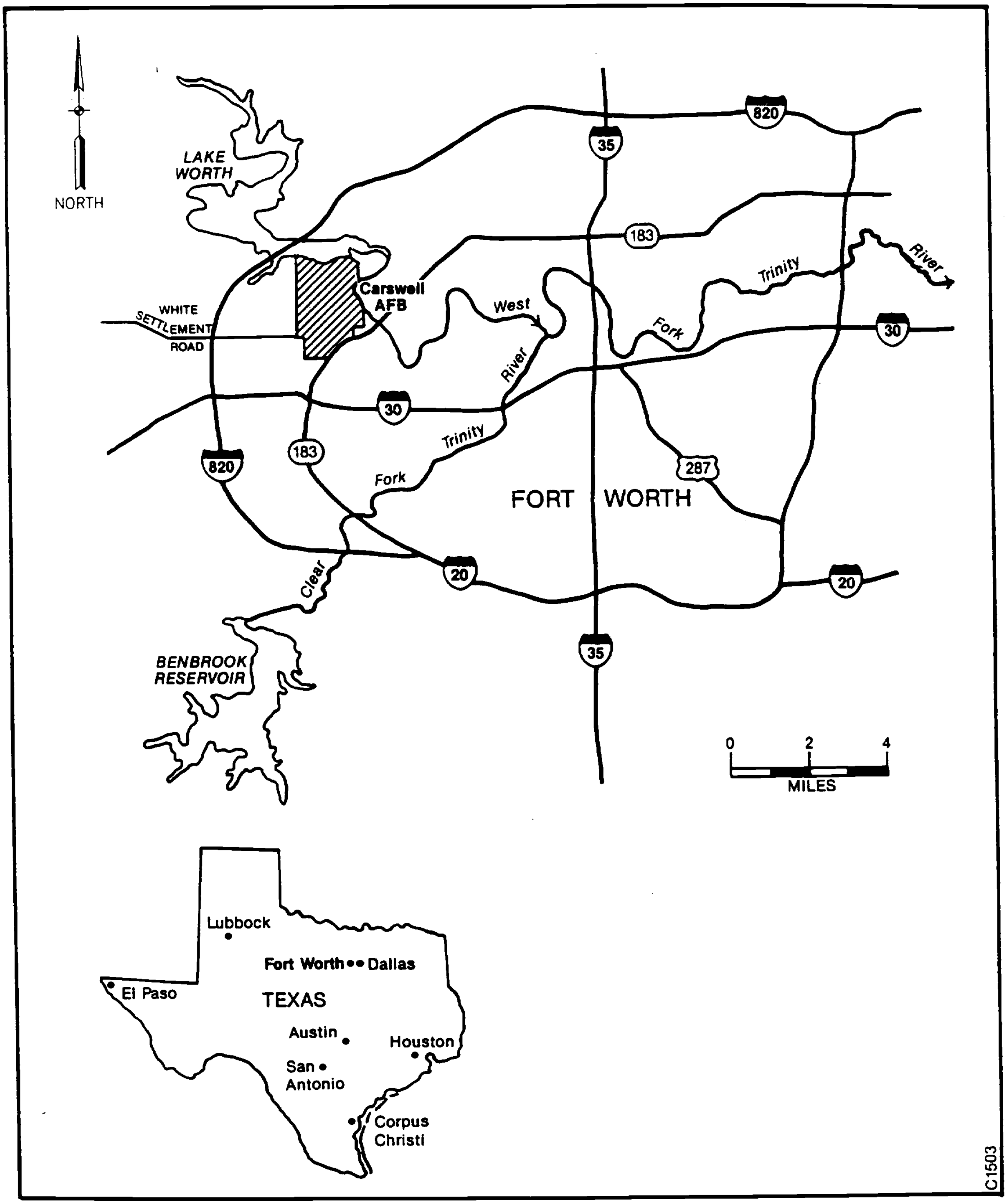

Figure 1-1. Regional Setting of Carswell AFB, Texas

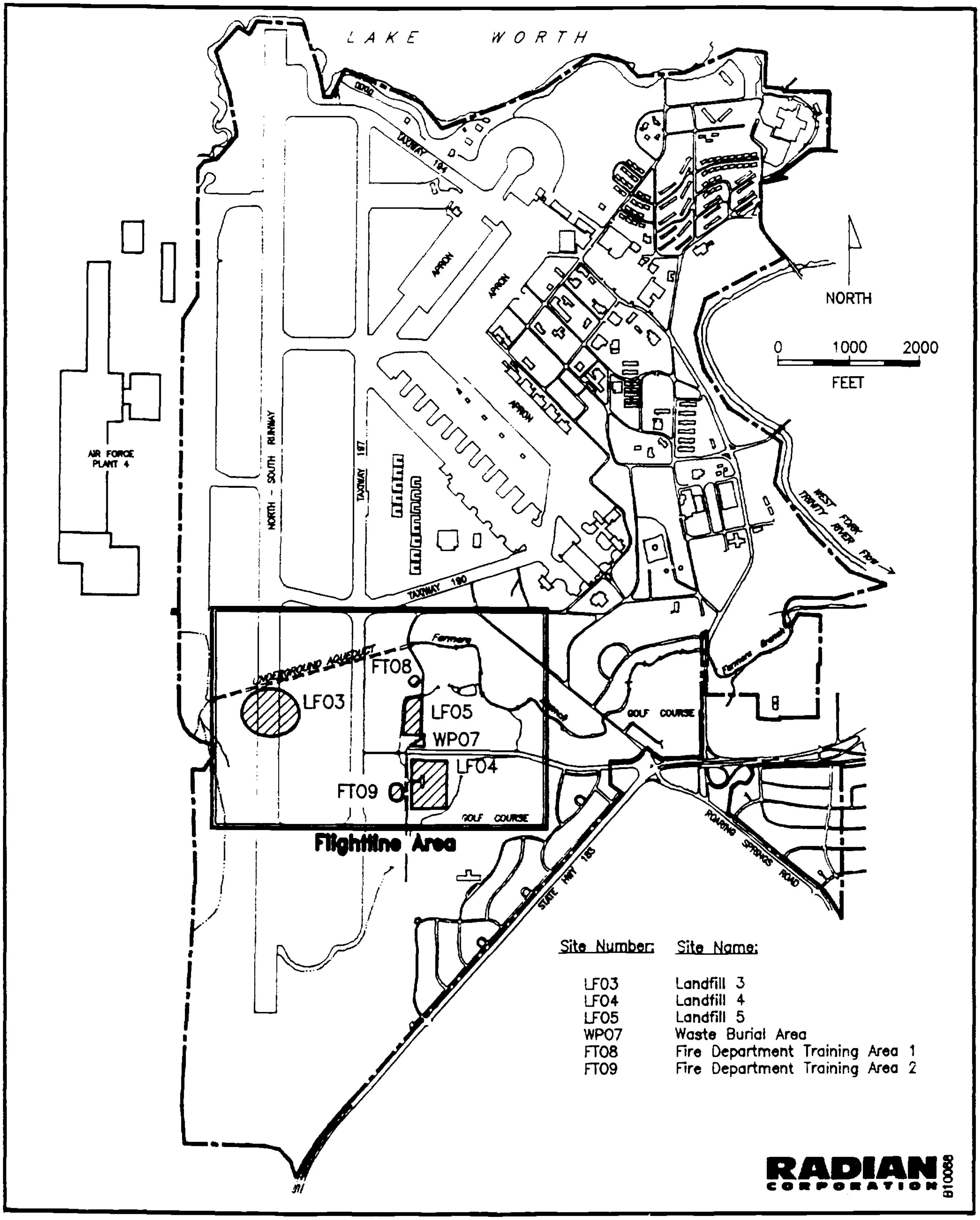

Figure 1-2. Location of Six Sites Included in the Flightline Area, Carswell AFB, Texas

physical features, historical uses, and the significant hydrogeologic findings from previous investigations performed in the Flightline Area. Historical descriptions of these sites and the wastes disposed of in each are taken from the Phase I Records Search (CH2M Hill, 1984).

1.2.1 Site LF04 - Landfill 4

Landfill 4 includes approximately 10 acres of land located east of the south end of Taxiway 197. It was the main landfill during much of the history of Carswell AFB. While in active use, at least six large pits, approximately 12 feet deep, were filled with refuse which was burned and buried. Various potentially hazardous wastes were reported disposed of at this site, including drums of waste liquids, partially full paint cans, and cadmium batteries.

1.2.2 Site LF05 - Landfill 5

Landfill 5 is located northwest of Landfill 4, adjacent to a small tributary to Farmers Branch. The landfill was constructed by building a clay berm along the creek and filling the area behind the berm up to the existing level. The landfill received all types of flightline wastes and refuse. Flightline wastes typically include such substances as oils, thinners, strippers, and paints. Waste materials in the landfill were burned regularly and buried.

1.2.3 Site WP07 - Waste Burial Area

Site WP07 is located adjacent to and north of White Settlement Road where it comes to a dead end at the taxiway. The area was used for burial of wastes during the 1960s. Various types of hazardous wastes, including drums of cleaning solvents, leaded sludge, and possibly ordnance were reportedly disposed of at this site.

1.2.4 Site FT09 - Fire Department Training Area 2

Site FT09 is located between Taxiway 197 and the radar facility. This site, with only slight modifications, has been used for fire department training exercises since 1963. The fire pit is lined with gravel and is enclosed by a low earthen berm. In the past, a second pit was present at the site to collect run-off from the training exercises, but it no longer exists.

1.3 Summary of Previous Flightline Area Investigations

The Flightline Area has been the subject of field investigations performed during two separate Stages of the IRP Phase II; the Stage 1 Preliminary Assessment (PA) and Stage 2 Site Inspection (SI). The Phase II Stage 1 investigation (Radian, 1986) documented contamination of shallow ground water and soils in the Flightline Area. The initial Phase II Stage 2 investigative activities helped define contaminants in the Flightline Area, both qualitatively and quantitatively. Radian conducted a second episode of field activities during the Phase II Stage 2 investigation (Radian, 1990c) to fill data gaps remaining after the initial Phase II Stage 2 effort (Radian, 1989). Most notably, these characterization efforts included:

- Source definition;
- Determination of surface water - ground water relationships;
- Definition of vertical and lateral extent of contamination; and
- Estimation of Upper Zone Aquifer hydraulic properties.

With information obtained from the additional Phase II Stage 2 activities, more complete characterization of contaminant source(s), surface water, geology, and ground water in the Flightline Area was achieved.

The following paragraphs summarize the activities performed throughout the Phase II IRP to characterize the contaminant sources and environmental media of concern in the Flightline Area at Carswell AFB. All field and analytical data from these investigations are contained in the various reports, including the Phase I investigation (CH2M Hill, 1984), the Phase II Stage 1 investigation (Radian, 1986), and the previous Phase II Stage 2 investigation (Radian, 1989).

1.3.1 Contaminant Source Characterization

The following activities were performed to characterize the source(s) of contamination identified in the Flightline Area:

- Determining the locations of the IRP hazardous waste sites in the Flightline Area;
- Delineating the lateral and vertical extent of the waste areas; and
- Assessing the chemical and physical characteristics of wastes disposed of in the Flightline Area IRP sites.

These activities were accomplished by completing the following tasks:

- Reviewing the Phase I Records Search and personnel interviews;
- Performing geophysical surveys to accurately define the lateral and vertical extent of the former waste disposal areas; and
- Collecting environmental samples (soil, ground water, and surface water) to determine the types and amounts of contaminants associated with individual waste disposal units within the Flightline Area.

1.3.2 Surface Water Characterization

The major surface water features associated with the Flightline Area are:

- Farmers Branch;
- An unnamed tributary that flows into Farmers Branch; and
- Two ponds located on the Carswell AFB golf course.

The following tasks were performed to characterize these surface water features:

- Chemical analysis of surface water samples collected from Farmers Branch, the unnamed tributary to Farmers Branch, and the two ponds located on the golf course;

- Estimating flow volumes at several locations on Farmers Branch and the small tributary; and

- Installing and surveying a staff gage in Farmers Branch to help determine ground-water/surface water relationships in the Flightline Area.

1.3.3 Geologic Characterization

The objectives of the geologic characterization activities performed in the Flightline Area were to:

- Determine the location of paleochannel(s) to assist in placement of Upper Zone monitor wells;

- Determine the depth to the shallow aquitard (Goodland/Walnut Formation) in the Flightline Area;

- Identify the thickness of the shallow aquitard under the Flightline Area; and

- Determine the depth to the uppermost regional potable water supply aquifer (Paluxy Aquifer) beneath the study area.

Radian accomplished these activities by completing the following tasks:

- Borehole drilling, sampling, and lithologic logging; and
- Performance of geophysical surveys.

1.3.4 Ground-Water Characterization

Investigations of the ground water occurring under the Flightline Area were limited to the Upper Zone and the Paluxy Aquifers. Previous investigations focused on these two aquifers because deeper aquifers are unlikely to be affected by downward migrating contaminants. This is due to the several hundred-foot thick section of low permeability Glen Rose Limestone that acts as a basal aquitard to the Paluxy Aquifer in this area. Activities were focused on defining ground-water quality, both upgradient and down-gradient of former waste disposal units in the Flightline Area, and on estimating aquifer properties. Characterization efforts were directed toward:

- Determining the physical and hydraulic properties of the aquifers;

- Identifying and quantifying the concentrations of contaminants in ground water from the Upper Zone and Paluxy Aquifer; and

- Delineating the lateral and vertical extent of ground-water contamination.

Radian performed the following tasks to characterize ground-water conditions in the Flightline Area:

- Test well installation in both the Upper Zone and Paluxy Aquifers;
- Sampling and describing the sediments that contain the ground water;
- Synoptic water-level surveys and potentiometric surface contouring;
- Performing in situ permeability tests (slug tests) and a pump test of the Upper Zone Aquifer;
- Ground-water sampling and analysis for waste-specific indicator parameters; and
- Mapping of ground-water contamination in the Flightline Area.

1.3.5 Findings of Previous Flightline Area Investigations

Geology

Based on the results of previous investigations (CH2M Hill, 1984; Radian, 1986, 1989, 1990c), the Flightline Area of Carswell AFB is characterized by surficial alluvial deposits of gravel, sand, silt and clay which are unconformably underlain by limestone and shale bedrock of the Cretaceous Goodland and Walnut Formations. The alluvium includes flood-plain and fluviatile terrace deposits which together constitute the Upper Zone, as defined by Hargis and Montgomery, Inc., 1983.

The base of the Upper Zone sediments was encountered during drilling activities performed in both RI/FS Phase II Stage 1 and Stage 2. In the Flightline Area, the Upper Zone varies from approximately 13 feet to greater than 40 feet thick. In general, silt and clay, with variable amounts of sand and gravel, dominate the upper five to 10 feet of the section. Below this depth, sand and gravel occur in increasing proportions, and in general, tend to increase in grain size with depth. Basal gravel deposits also occur in paleochannel features eroded into the surface of the underlying bedrock. The gravel consists mainly of limestone and shell fragments that range in size from fine gravel to cobbles.

The bedrock was penetrated during drilling of the Paluxy Aquifer monitor wells in the Stage 2 study, and was encountered at the base of a number of the Upper Zone monitor wells installed in Stage 1 and Stage 2. Bedrock in the Flightline Area consists of interbedded fossiliferous limestone and calcareous shale of the Goodland and the Walnut Formations. These units are generally dry, although small amounts of water were occasionally observed in the shale and clay units during drilling activities.

The bedrock surface is level across most of the Flightline Area east of Taxiway 197, but rises sharply near the southwest part of Site FT09 and the southern part of Site LF04, in the vicinity of the outcrop south of the study area. The locally irregular topography of the bedrock surface is typical of an erosional surface modified by fluvial processes.

Ground Water

Ground water occurs in the Upper Zone and in the Paluxy Aquifer beneath the Flightline Area. The potentiometric surface of ground water in the Upper Zone tends to mirror the configuration of the alluvium/bedrock contact. The position of the water table also reflects to a lesser degree the land surface topography. Downgradient is generally to the east toward a tributary of Farmers Branch, parallel to the surface slope. The hydraulic gradient is very low (on the order of 16 feet per mile) beneath most of the Flightline Area, except in the extreme southwestern area where it is notably steeper.

IRP Stage 1 ground-water analytical results revealed Upper Zone contamination by several volatile organic compounds, most notably TCE at concentrations ranging up to approximately 5000 micrograms per liter ($\mu g/L$). Soil samples from the Flightline Area also contained detectable concentrations of TCE. Most of the detected contamination was apparently centered to the east of the Flightline Area at the golf course, but TCE concentrations up to nearly 3300 $\mu g/L$ were also detected in samples from wells located upgradient of Landfill 5, within 900 feet of the flightline. No contaminants were detected in the Paluxy Aquifer monitor wells.

During the Stage 2 effort, flightline monitor wells were sampled in January-February, and again in April, 1988. The following analytes were detected in concentrations above their respective EPA Maximum Contaminant Levels (MCLs) in one or more samples: arsenic, barium, cadmium, chromium, lead, selenium; and trichloroethylene, vinyl chloride, and benzene. Of the metals detected in concentrations exceeding their MCLs, chromium was the most widespread. However, all metals analyses were performed on unfiltered ground-water samples, and therefore reflect total, rather than dissolved metals concentrations.

As determined in Stage 1, the dominant organic contaminant identified in Stage 2 Upper Zone ground-water samples was TCE. The extent of the TCE plume in the Flightline Area was not completely defined upgradient (west) or downgradient (north and east) of the flightline IRP sites. Based on the generally west-to-east shallow ground-water flow direction, the existence of TCE in samples from monitor wells located west of the IRP sites was interpreted as indicating one or more additional upgradient sources not related to the sites subject to ongoing investigation. Also, TCE contamination of Upper Zone ground water in the area east of Air Force Plant 4 (i.e., upgradient of the Carswell AFB Flightline Area) is documented (Hargis and Associates, 1989).

Additional Stage 2 activities in the Flightline Area were recommended to: 1) determine to what extent, if any, the TCE-contaminated Upper Zone ground water east of Plant 4 and that beneath the Flightline Area constitute a contiguous plume; 2) determine to what extent, if any, the IRP sites on Carswell AFB are contributing to the existing Upper Zone ground-water contamination; 3) define the maximum lateral, downgradient, and vertical extent of the contaminant plume on Carswell AFB; and 4) define the site-specific hydrogeological characteristics of the Upper Zone in the Flightline

Area in sufficient detail to design and implement an appropriate remedial action.

1.4 Report Organization

Following this Introduction, the field activities performed to characterize the Flightline Area are described in Section 2. The techniques and methodologies used to accomplish the field program are presented in detail with respect to the contaminant source, surface water, geological, and ground-water investigations that were included in the comprehensive Phase II scope of work. Section 3 presents a detailed description of the physical environmental setting of the Flightline Area based on interpretation of data from the current investigation and from previous studies. The nature and extent of surface water and ground-water contamination, determined from the most recent round of sampling and analysis (May-June 1990) are discussed in Section 4, and Section 5 addresses contaminant fate and transport. Section 6 summarizes the baseline risk assessment methodology and results of the evaluation; and presents the Defense Priority Model (DPM) ranking of the Flightline Area. Section 7 summarizes the major findings of the RI and presents the conclusions regarding data limitations and recommendations for additional activities.

2.0 FIELD TECHNIQUES AND ANALYTICAL METHODS

Several field techniques were used to obtain information on the environmental conditions of the Flightline Area. The following subsections describe the techniques for drilling and soil sampling (including analytical methods, holding times, and collection and preservation requirements), the methods for conducting geophysical surveys, the methods and specifications for well construction and development, the techniques for collecting water samples (including analytical methods, holding times, and collection and preservation requirements), aquifer test methods, and surveying requirements.

2.1 Drilling and Soil Sampling

Drilling at Carswell AFB was accomplished using a hollow-stem auger rig for the Upper Zone monitor wells and soil borings and a rotary drilling rig (using both mud and air) for the Paluxy monitor wells. These methods were selected based on site-specific conditions and data requirements; i.e., the anticipated depth of completion, the need for water-level observations during drilling, and the expected geologic conditions.

After each borehole was completed, the drilling rig, auger flights, and equipment were decontaminated with a high temperature, high pressure steam-sprayer using base potable water.

Cuttings suspected of being contaminated on the basis of visual evidence and organic vapor analyzer (OVA) or photoionization detector (HNu) readings were placed in steel 55-gallon drums. Selected samples of cuttings were collected and submitted for analysis of EP Toxicity.

The following paragraphs describe the drilling and soil sampling procedures.

2.1.1 Hollow-Stem Augering

A Mobile Drill B-61 or a CME-75 hollow-stem auger drilling rig was used to perform shallow soil borings and installation of the Upper Zone monitor wells. The hollow-stem auger method allows for recovery of relatively undisturbed subsurface soil cores, determination of subsurface lithologies and structures, and accurate identification of the position of the water table. The boreholes were drilled dry; no drilling fluids or additives were used. Samples of soil were collected with either a split-spoon sampler, a thin-wall sampler (Shelby tube), or a CME 5-foot continuous core sampler.

The soil samples were described in terms of lithology, moisture content and any evidence of contamination. Lithologic logs of boreholes drilled during the most recent field activities are provided in Appendix A. Photographs of selected soil cores showing lithologic characteristics were also taken.

Selected samples were shipped on ice to Radian's laboratory for chemical analysis. Analytical parameters for soil samples are listed in Table 2-1. No soil samples were collected for chemical analysis in the most recent Stage 2 effort.

2.1.2 Air and Mud Rotary Drilling

Air and mud rotary drilling was performed during the Phase II Stage 1 program (Radian, 1986) with a Gardner-Denver 1500 CD truck-mounted rig. A 6-inch bit was used to advance a pilot borehole through the Upper Zone alluvial material to a depth of at least five feet into the underlying Goodland Limestone. The borehole was then reamed to a diameter of 14 inches. In order to seal off different water bearing zones, a 10-inch diameter steel casing was installed to the full depth of the borehole and the annular space was grouted. Upon achieving a positive seal, the borehole was advanced using a 6-inch diameter bit to the final depth at the shale unit separating the upper and lower Paluxy Formation. Bentonite drilling fluid was used while

TABLE 2-1. SUMMARY OF RI/FS PHASE II SOIL SAMPLING AND ANALYSIS REQUIREMENTS, CARSWELL AFB, TEXAS

Reference Method	Parameter	Method Detection Limit	Method Type[1]	Container Type, No. and Volume	Preservation and Storage Requirements	Sample Extraction Procedures	Maximum Holding Time (Preparation)[2]	Maximum Holding Time (Analysis)
EPA 6010	Metals	0.2 - 90 µg/g	ICP	250 mL glass bottle	Refrigerated at 4°C	Acid digestion (3050R)	N/S	6 months
EPA 7060	As	0.5 µg/g	Furnace AA	250 mL glass bottle	Refrigerated at 4°C	Acid digestion (3050R)	N/S	6 months
EPA 7740	Se	0.5 µg/g	Furnace AA	250 mL glass bottle	Refrigerated at 4°C	Acid digestion (3050R)	N/S	6 months
EPA 7471	Hg	0.5 µg/g	Cold Vapor AA	250 mL glass bottle	Refrigerated at 4°C	Acid digestion (3050R)	N/A	28 days
EPA 7420	Pb	0.5 mg/g	AA (furnace)	250 mL glass bottle	Refrigerated at 4°C	Acid digestion (3050R)	N/S	6 months
EPA 413.2	Oil and Grease	10 µg/g	IR	250 mL glass bottle	Refrigerated at 4°C	Freon extraction by sonication (2550)	N/S	28 days
EPA 418.1	Petroleum Hydrocarbons	50 µg/g	IR	250 mL glass bottle	Refrigerated at 4°C	Sonication extraction (3550) with freon	N/S	28 days
EPA 8240	Volatile Organic Compounds	0.1 µg/g	GC/MS	250 mL glass bottle	Refrigerated at 4°C	Purge and trap (5030)	14 days	14 days
EPA 8270	Semi-Volatile Organic Compounds	1 µg/g	GC/MS	250 mL stainless steel sleeve or 250 mL glass bottle	Refrigerated at 4°C	Sonication (3550)	14 days	40 days
EPA 8150	Chlorinated Phenoxy Herbicides	0.1 - 160 µg/g	GC/ECD	250 mL glass bottle	Refrigerated at 4°C	Extraction, hydrolysis, GC	7 days	40 days
EPA 8080	Organochloride Pesticides and PCB's	0.01 - 0.2 µg/g	GC/ECD	250 mL glass bottle	Refrigerated at 4°C	Sonication extraction (3550)	7 days	40 days

Notes: 1. ICP = Inductively Coupled Plasma Emission Spectroscopy
AA = Atomic Absorption
IR = Infrared Spectroscopy
GC/PID = Gas Chromatograph/Photoionization Detector
GC/HSD = Gas Chromatograph/Halide Specific Detector
2. N/A = Not Applicable
N/S = Not Specified
SM = Standard Method

(Continued)

TABLE 2-1. (Continued

Reference Method	Parameter	Method Detection Limit	Method Type[1]	Container Type, No. and Volume	Preservation and Storage Requirements	Sample Extraction Procedures	Maximum Holding Time (Preparation)[2]	Maximum Holding Time (Analysis)
40 CFR 261.21 (EPA 1310)	EP Toxicity	0.002-0.5 mg/L	AA, ICP	250 mL glass bottle	Refrigerated at 4°C	Extraction	N/S	28 days
EPA 8140	Organophosphorus Pesticides	0.5 - 5 µg/g	GC	250 mL glass bottle	Refrigerated at 4°C	Sonication, extraction (2550) with freon	7 days	40 days
ASTM D2216	Soil Moisture							

Notes: 1. ICP = Inductively Coupled Plasma Emission Spectroscopy
AA = Atomic Absorption
IR = Infrared Spectroscopy
GC/PID = Gas Chromatograph/Photoionization Detector
GC/HSD = Gas Chromatograph/Halide Specific Detector
2. N/A = Not Applicable
N/S = Not Specified
SM = Standard Method

drilling in the Paluxy Formation owing to borehole instability during air rotary operations.

As the borehole was advanced, the cuttings discharged at the surface were described by lithology, moisture content (air rotary-drilled section), evidence of contamination, and other features useful in characterizing the geologic section. Drilling conditions, such as relative rate and ease of penetration, were noted by the driller. Water encountered during drilling was noted with respect to depth of occurrence and rate of production. As needed, drilling was suspended temporarily to allow for recovery of water in the borehole.

2.2 Geophysical Surveys

Geophysical surveys were performed to define the vertical and lateral extent of waste-disposal activities, to provide a clearer picture of the subsurface conditions around the sites, and to investigate the potential existence of buried objects at several locations. Most geophysical tasks were performed during Phase II Stage 1; only a magnetometer survey of WP07 (formerly Site 10) was performed during the initial Stage 2 investigation.

All survey grids were laid out using a compass and measuring chain. Stations were marked with labelled pin flags or spray paint. The geophysical techniques employed in the Flightline Area characterization efforts were earth resistivity, magnetic and magnetic gradient, and fixed frequency electromagnetic profiling (EMP) conductivity. The Earth Technology Corporation of Golden, Colorado performed the geophysical surveys in the Flightline Area. Following are brief descriptions of the various geophysical techniques used to characterize the Flightline Area.

2.2.1 Electrical Resistivity

Earth resistivity was measured by direct current Schlumberger soundings (vertical electrical soundings - VES) at all IRP sites in the Flightline Area. The Bison Model 2350 Earth Resistivity meter was utilized for the VES measurements. Current electrode separations used were (in meters): 1, 2, 3, 4, 6, 10, 14, 20, 30, 40, and 50 (1 meter equals 3.28 feet). Due to variable ground conductivity, potential electrode separations varied slightly from site to site. The sounding data were processed using the ABEM VES iteration process to obtain a best fit curve and were plotted logarithmically as resistivity in ohm-meters versus half the current electrode separation in meters. The plot also includes the layered earth model giving the best match. At most VES sites, orthogonal electrode arrays were used to test for distortions of the data due to lateral inhomogeneities in the ground.

2.2.2 Electromagnetic Surveys

Electromagnetic profiling (EMP) surveys were conducted at Flightline Area Sites LF03, LF04, LF05, WP07, FT08, and FT09 using two devices: the Geonics EM31 and the Geonics EM34-3 ground conductivity sensors. Both ground conductivity sensors are designed for rapidly obtaining data over large areas. The meters employ magnetic dipoles or magnetic induction loops for transmission and reception of low frequency electromagnetic waves. The effective depth of investigation of the EM31 is six meters; the depth of investigation provided by the EM34-3 depends on the coil separation and orientation, applied frequency, and to some extent, the conductivity profile of the subsurface. The techniques and conditions at Carswell AFB resulted in an effective investigation depth of 50 feet with the EM34-3. The resulting data are reported in units of millimhos/meter.

2.2.3 Magnetometer Surveys

Magnetometer surveys were accomplished using either an EDA PPM500 proton magnetometer or a Geometrics G856AX magnetometer. Magnetometer surveys were performed because the over-burden at Carswell has a low magnetic susceptibility; the buried objects were believed to contain a significant amount of iron that would create a noticeable magnetic anomaly. Readings of the total field and magnetic gradient were taken at each location. The units for these readings are gammas and gammas per one-half meter (1.64 feet), respectively. The magnetometer survey of WP07 during Phase II Stage 2 activities was performed to determine if metal objects were buried at any of the proposed drilling locations.

2.3 Monitor Well Construction and Development

During the Phase II activities in the Flightline Area, a total of 35 Upper Zone monitor wells and two Paluxy Aquifer monitor wells were installed. The construction specifications and well development procedures are described in the following sections. One aquifer (pump) test well and an observation well were also completed in the Upper Zone. The construction of these wells is described in Section 2.5 (Aquifer Pumping Test).

2.3.1 Upper Zone Well Construction

Upper Zone monitor wells were installed either immediately after completion of the drilling operations or after the borehole produced enough water to warrant a well. Construction specifications for the Upper Zone monitor wells are presented in Table 2-2. Well completion summaries for Flightline Area monitor wells completed in the most recent (1990) investigation are provided in Appendix B. Construction methods were generally consistent with the specifications provided in the SOW. Any changes necessitated by unanticipated field conditions were made with the knowledge and approval of the HSD/YAQ Technical Program Manager. Decisions regarding the setting of the screen and casing, length of screen, amount of sand pack and bentonite were made in the field by the Radian Supervising Geologist based on the static water level and saturated thickness of Upper Zone sediments. Monitor wells were installed using the following procedures:

1. Prior to installation, the casing and screen sections were thoroughly washed using a high temperature, high-pressure steam sprayer, with base potable water.

TABLE 2-2. UPPER ZONE MONITOR WELL CONSTRUCTION SPECIFICATIONS, FLIGHTLINE AREA, CARSWELL AFB, TEXAS

1. Casing: Two-inch diameter, threaded and flush jointed, Schedule 40 PVC.

2. Screen: Two-inch diameter, threaded and flush-jointed factory-slotted, Schedule 40 PVC, 0.020 inch slot. Normal screen length is 10 feet. Some well screens were wrapped with filter fabric material.

3. Sand/gravel pack: Washed and bagged, rounded sand/gravel with grain size compatible with screen slot and formation (Coarse, No. 8-20). A sand pack was placed from the bottom of the borehole to two to five feet above the top of the well screen. Sand was placed at a controlled rate to avoid bridging within the auger.

4. Bentonite seal: Two feet (minimum) of pelletized bentonite placed above the sand pack.

5. Grout: Type II Portland cement grout poured into the annular space from the top of the bentonite seal to land surface. A grout mixture consisting of approximately four pounds of bentonite to 94 pounds of cement was used. The grout was allowed to set for at least 24 hours before any well development activities.

6. Surface completion: PVC casing cut off to provide a 2- to 3-foot stickup with a solid cap placed on the casing. A 4- to 6-inch square steel well protector, four to five feet in length, was placed over the exposed PVC casing, and seated in the cement. A locking cap is incorporated in the well cover. Steel guard posts were installed as described in (8) below. The steel well protector and steel guard posts were painted for corrosion control and visibility.

7. Alternate flush completion: PVC casing cut off two to three inches below land surface, with a cast-iron valve box cemented in place. To prevent any surface water infiltration, the valve box is slightly elevated above land surface and the surrounding concrete is sloped away from the well. The lid to the valve box is secured with allen bolts. Most wells located on the heavy traffic areas of the Carswell AFB golf course were completed flush with the land surface.

8. Guard pipes or posts: Three 3-inch diameter steel posts, six feet in length, with a minimum of two feet below ground, installed radially four feet from the wellhead (not emplaced for flush surface completion).

2. Screen and casing sections were assembled, then lowered carefully into the borehole. As the string of screen and casing was lowered, additional sections of casing were added until the bottom of the screen reached the bottom of the borehole. The top of the casing was capped to prevent any completion materials (sand, bentonite pellets, and grout) from entering the casing during well construction activities. Where heaving or flowing sand was encountered, some well screens were wrapped in a filter fabric and installed using a natural, rather than artificial, sand pack. These wells were LF04-4F and -4H, and LF05-5F, -5G, and -5H.

3. Except as previously noted, clean sand (Coarse, No. 8-20) was poured carefully inside the annular space as the augers were slowly withdrawn from the borehole. The sand pack was regularly measured by the supervising geologist until the level of the sand was at least 2 feet above the top of the screen. Bentonite pellets were placed above the sand to form a 2-foot thick seal (minimum). If necessary, water bailed from the borehole was poured down the annular space to hydrate the bentonite.

4. Neat cement grout containing approximately four percent bentonite was either emplaced through the augers as they were withdrawn, or slowly poured down the borehole, if the formation was sufficiently consolidated to remain open.

5. After completion of grouting, the casing was cut two to three feet above land surface and a protective 4- to 6-inch diameter steel casing protector with a lockable lid was cemented into place. Three steel guard posts were then placed around the well. If above-ground stickups were of concern in an area, the well was completed flush with the land surface. For flush completions, the lid to the valve box was secured with allen bolts.

After all wells were completed, well locations and elevations were professionally surveyed. Table 2-3 presents the elevations of the ground surface, the wellhead, and the screened interval of the Upper Zone monitor wells in the Flightline Area.

2.3.2 Paluxy Formation Well Construction

After drilling operations were completed as described in Section 2.1, two Paluxy Aquifer monitor wells were installed as follows: Screen and casing, consisting of 5-inch diameter Schedule 80 PVC, were installed into the 10-inch diameter borehole. Screen length was 37.5 feet. Gravel pack material (Texas Blast Sand No. 1A) was placed in the annular space to a level of five feet above the top of the screen. Bentonite pellets were added to form a 2-foot thick seal, and the remaining annular space was sealed to the surface by the tremie method using bentonite-cement grout. After the grout was allowed to set for a minimum of 24 hours, the well was developed by bailing until a sediment-free discharge was produced. A 1/3 horsepower stainless steel submersible pump was installed after development. Protective casing, surface electrical connections, and a concrete well pad were placed after the pump was installed.

2.3.3 Well Development

After allowing the cement grout to set-up for a minimum of 24 hours, the Upper Zone wells were developed by either bailing using a bottom-entry bailer or pumping with a Triloc® hand pump (1.7-inch diameter). As previously stated, Paluxy Aquifer monitor wells were developed by bailing.

Water levels in some of the Upper Zone wells recovered slowly and the wells were bailed dry several times. Other wells produced sufficient water and were developed in a single effort, without a recovery period. Development was considered complete when the water in the well was as sediment free as possible. The pH, temperature and conductivity of the development discharge water were measured and recorded at frequent intervals. The ground water removed from the wells was placed in steel 55-gallon drums, sealed and

TABLE 2-3. SPECIFICATIONS FOR FLIGHTLINE AREA UPPER ZONE MONITOR WELLS, CARSWELL AFB, TEXAS

Monitor Well Number	Previous Monitor Well Number	Measuring Point[1] Elevation (feet MSL)	Ground Level Elevation (feet MSL)	Screened Interval (feet BLS)	Screen Elevations (feet MSL)	Total Depth (feet BLS)
LF03-3D	3D	625.25	621.6	8.5-14.4	613.1-607.2	15.4
LF04-4A	4A	625.76	624.6	14-24	610.6-600.6	24.0
LF04-4B	4B	619.90	618.4	13-23	605.4-595.4	24.0
LF04-4C	4C	613.04	610.9	18.5-28.5	592.4-582.4	29.5
LF04-4D	4D	615.35	613.1	18-28	595.1-585.1	30.5
LF04-4E	4E	618.54	617.5	15-35	602.5-582.5	35.0
LF04-4F	4F	625.36	622.8	21-34	601.8-588.8	35.0
LF04-4G	4G	620.02	619.1	22-35	597.1-584.1	36.0
LF04-4H	4H	613.43	610.5	14-27	596.5-583.5	28.0
LF04-01	NA	629.24	626.5	30.0-39.7	596.6-586.8	40.1
LF04-02	NA	623.68	621.0	23.1-37.5	597.9-583.6	37.7
LF04-03	NA	623.25	620.5	22.4-36.7	598.1-583.8	37.6
LF04-04	NA	612.07	609.4	15.2-24.9	594.2-584.5	25.2
LF04-10	NA	626.54	626.9	39.2-49.0	587.7-577.9	49.5
LF05-5A	5A	623.18	619.4	18-28	601.4-591.4	32.0
LF05-5B	5B	600.45	597.4	4-9	593.4-588.4	9.0
LF05-5C	5C	608.68	606.8	7-22	599.8-584.8	22.0
LF05-5D	5D	611.71	608.5	10.5-19.5	598.0-589.0	20.5
LF05-5E	5E	626.89	623.9	25.1-38.1	598.8-585.8	39.1
LF05-5F	5F	618.95	619.4	23-36	596.4-583.4	37.0
LF05-5G	5G	615.39	612.0	15.3-26	596.8-586.0	27.0
LF05-5H	5H	610.62	608.4	13.9-24.6	594.6-583.8	25.6
LF05-01	NA	621.96	619.3	15.0-24.7	604.4-594.6	25.2
LF05-02	NA	622.69	620.0	17.0-26.7	603.1-593.3	27.2

Notes: 1. Measured from top of casing.
MSL - Mean Sea Level
BLS - Below Land Surface

(continued)

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TABLE 2-3. (Continued)

Monitor Well Number	Previous Monitor Well Number	Measuring Point[1] Elevation (feet MSL)	Ground Level Elevation (feet MSL)	Screened Interval (feet BLS)	Screen Elevations (feet MSL)	Total Depth (feet BLS)
LF05-14	NA	602.98	603.2	5.1-13.0	598.1-590.2	13.3
LF05-18	NA	611.84	612.1	13.9-23.7	598.2-588.5	23.95
LF05-19	NA	606.08	606.3	10.3-20.0	596.1-586.3	20.75
WP07-10A	10A	626.7	626.7	27-37	599.7-589.7	39.0
WP07-10B	10B	624.46	621.1	23-33	598.1-588.1	36.0
WP07-10C	10C	617.24	615.4	20-30	595.4-585.4	32.5
FT08-11A	11A	608.22	604.8	4-14	600.8-590.8	14.5
FT08-11B	11B	608.14	603.8	3.5-13.5	600.3-590.3	15.0
FT09-12A	12A	635.66	632.0	13-23	619.0-609.0	25.0
FT09-12B	12B	627.55	625.6	27.5-37.5	598.1-588.1	40.0
FT09-12C	12C	628.05	625.5	27.5-37.5	598.0-588.0	38.0
FT09-12D	12D	627.45	624.8	21.4-34.4	603.4-590.4	35.4
FT09-12E	12E	627.48	624.5	24-27.5	600.5-597.0	38.5

Notes: 1. Measured from top of casing.
MSL - Mean Sea Level
BLS - Below Land Surface

appropriately labeled, based on field observations. Well development logs for the most recently installed (1990) monitor wells in the Flightline Area are provided in Appendix C.

2.4 Water Sampling

Both ground-water and surface water samples were collected from the Flightline Area. The following subsections describe the sampling techniques and methodologies for the various water samples collected during IRP Phase II investigations. Ground-Water and Surface Water Quality Sampling Records for the most recent round of Stage 2 sampling, including measurements of pH, conductivity, and temperature; and information such as volumes of water purged prior to sampling are provided in Appendix D.

2.4.1 Surface Water Sampling

Surface water grab samples were collected directly in the clean sample containers to minimize sample handling (and possible cross-contamination). The samples were collected approximately six inches below the water surface, or half-way between the water surface and the bed of the stream if the stream was not six inches deep. During the most recent (1990) field activities, surface water samples were collected at Farmers Branch, a small tributary that runs into Farmers Branch, and two ponds located on the Carswell AFB golf course. Additionally, during the most recent Stage 2 investigation (1990), estimates of flow volume were made at each surface water sample location at the time of collection.

Specific conductance, pH and temperature were measured on an aliquot of each sample. Specific conductance and pH were measured with a DSPH-1 meter and the temperature was taken with a mercury thermometer. Alkalinity measurements were made in the field using a Hach Alkalinity Test Kit (Model AL-DT) and digital titrator. Prior to obtaining the field measurements, the pH meter was calibrated with pH 4, 7, and 10 standard solutions and the conductivity meter was calibrated using either a 1413 or a 1504 umhos/cm KCl conductivity standard solution.

2.4.2 Ground-Water Sampling

Prior to sample collection, water levels were measured in each of the monitor wells with an Olympic Actat water level meter, and were recorded in a field notebook or on appropriate IRPIMS data collection forms. Measurements were taken from the surveyed mark point at the top of the casing, and read to the nearest 0.01-foot. Between measurements, the probe and associated electrical line were washed with laboratory grade detergent, rinsed with potable water, and then rinsed with deionized water to reduce the possibility of cross-contamination.

Before samples were collected, a minimum of three well volumes of water were bailed from the well using a bottom-entry Teflon™ bailer attached to a nylon monofilament line. This procedure ensured that representative formation water was collected. Purged water was placed in 55-gallon drums for final disposal pending the outcome of chemical analyses (provided to the Base Environmental Coordinator). Between wells, all equipment used for bailing operations was cleaned with laboratory grade detergent (Alconox), rinsed with potable water, ASTM Type II Reagent Water (or approved equivalent), pesticide-grade methanol, and finally pesticide-grade hexane. The equipment was allowed to air dry completely before reuse. The nylon line was replaced between wells.

Specific conductance, pH, temperature, and alkalinity were determined as described for surface water. On a few occasions, field measurements could not be made due to instrument malfunction.

After each well was purged of the required volume of water, ground-water samples were collected using a Teflon bailer. After collection, samples were placed directly into prelabeled sample bottles and preserved according to the requirements listed in Table 2-4. Ground-water samples for dissolved metals were filtered in the field. Samples were placed in ice chests with ice and were shipped for overnight delivery to Radian's laboratories in Sacramento, California, or Austin, Texas; or were hand delivered to the laboratory in

TABLE 2-4. SUMMARY OF FLIGHTLINE AREA WATER SAMPLING AND ANALYSIS REQUIREMENTS, CARSWELL AFB, TEXAS

Reference Method	Parameter	Method Detection Limit	Method Type[1]	Container Type, No. and Volume	Preservation and Storage Requirements	Sample Extraction Procedures	Maximum Holding Time (Preparation)[2]	Maximum Holding Time (Analysis)
SM403	Alkalinity-Carbonate, Bi-carbonate & Hy-droxide (Field Test)	10 mg/L	Titration	(1) 1-Liter Polyethylene or Borosilicate glass bottle	Refrigerated at 4°C	None	N/S	Analyze immediately
EPA 120.1	Specific Conductance (Field Test)	N/S	Wheatstone Bridge-type conductivity meter	None	None	None	N/A	Analyze immediately
EPA 150.1	pH (Field Test)	N/S	Electrometric pH meter	None	None	None	N/A	Analyze immediately
EPA 170.1	Temperature (Field Test)	N/A	Thermometric	(1) 500 mL plastic bottle	None	None	N/A	Analyze immediately
EPA 200.7	Metals	0.002-0.9 mg/L	ICP	(1) 500 mL polyethylene bottle	pH<2 w/HNO_3	HNO_3/HCl digestion	N/S	6 months
EPA 206.3	As	4 µg/L	AA (furnace)	(1) 500 mL	pH<2 w/HNO_3	HNO_3 digestion	N/S	6 months
EPA 270.3	Se	2 µg/L	AA (furnace)	Polyethylene	pH<2 w/HNO_3	HNO_3 digestion	N/S	6 months
EPA 245.1	Hg	0.2 µg/L	AA (vapor)	(1) 500 mL polyethylene bottle	pH<2 w/HNO_3	$KMnO_4$, HNO_3, H_2SO_4 digestion	N/S N/S	6 months 28 days
EPA 239.2	Pb	0.005 µg/L	AA (furnace)	(1) 500 mL Polyethylene	4°C, pH < 2 w/HNO_3	HNO_3 digestion	N/S	6 months
EPA 413.2	Oil and Grease	0.2 µg/L	IR	(1) 1000 mL glass bottle	pH<2 w/HCl refrigerated at 4°C	Freon extraction	N/S	28 days
EPA 418.1	Petroleum Hydrocarbons	1 mg/L	IR	(1) 1-L glass bottle	4°C, pH<2 w/HCl	Freon extraction	N/S	28 days
EPA 160.1	Total Dissolved Solids	10 mg/L	Gravimetric	(1) 1000 mL plastic bottle	Refrigerated at 4°C	N/A	None	14 days

Notes: 1. ICP = Inductively Coupled Plasma Emission Spectroscopy
AA = Atomic Absorption
IR = Infrared Spectroscopy
GC/PID = Gas Chromatograph/Photoionization Detector
GC/HSD = Gas Chromatograph/Halide Specific Detector
2. N/A = Not Applicable
N/S = Not Specified
SM = Standard Method

(Continued)

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TABLE 2-4. (Continued)

Reference Method	Parameter	Method Detection Limit	Method Type[1]	Container Type, No. and Volume	Preservation and Storage Requirements	Sample Extraction Procedures	Maximum Holding Time (Preparation)[2]	Maximum Holding Time (Analysis)
EPA 8020	Purgeable Aromatics	0.2-0.4 µg/L	GC/PID	(3) 40 mL VOA vial w/Teflon septa	pH<2, w/1:1 HCl, refrigerated at 4°C	Nitrogen purge	N/S	14 days
EPA 601	Purgeable Halocarbons	0.02-5 µg/L	GC/HSD	(3) 40 mL VOA vial w/Teflon septa	Refrigerated at 4°C	Nitrogen purge	N/S	14 days
EPA 325.3	Chloride	1 mg/L	Titration	(1) 1-L Polyethylene	Refrigerated at 4°C	None	N/S	28 days
EPA 240.2	Fluoride	0.1 mg/L	Ion Selective Electrode	(1) 1-L Polyethylene	Refrigerated at 4°C	None	N/S	28 days
EPA 353.1	Nitrate	0.02 mg/L	Colorimetry	(1) 500 mL Polyethylene	4°C, pH<2 w/H_2SO_4	None	N/S	14 days
EPA 375.4	Sulfate	1 mg/L	Turbidimetry	(1) 1-L Polyethylene	Refrigerated at 4°C	None	N/S	28 days
EPA 365.1	O-Phosphate	0.02 mg/L	Colorimetry	(1) 500 mL Polyethylene	4°C, pH<2 w/H_2SO_4	None	N/S	28 days
EPA 604	Phenols	0.5 - 80 µg/L	GC	(2) 1-L glass bottle	Refrigerated at 4°C	Methylene chloride extraction	7 days	40 days
EPA 625	Priority Pollutants	50 µg/L	GC/MS	(2) 1000 mL glass; TFE-lined cap	Refrigerated at 4°C	Continuous extraction with methylene chloride	7 days	40 days
EPA 608	Organochloride Pesticides	0.05 - 1 µg/L	GC	(2) 1-L glass bottle	4°C pH 5 to 9	Methylene chloride extraction	7 days	40 days
SM509b	Chlorinated Phonoxy Acid Herbicides	0.01 µg/L	GC	1-L glass bottles w/TFE lined caps	4°C	Hydrolyze, esterify	7days	40 days

Notes: 1. ICP = Inductively Coupled Plasma Emission Spectroscopy
AA = Atomic Absorption
IR = Infrared Spectroscopy
GC/PID = Gas Chromatograph/Photoionization Detector
GC/HSD = Gas Chromatograph/Halide Specific Detector
2. N/A = Not Applicable
N/S = Not Specified
SM = Standard Method

Austin. To ensure that sample integrity was maintained during shipping and handling, custody seals were affixed to each ice chest and chain-of-custody forms were completed and transmitted with the samples to each laboratory.

2.5 Aquifer Testing

Single-well in situ permeability aquifer tests (i.e., slug tests) and an aquifer pumping test were performed to determine the hydraulic properties of the Upper Zone Aquifer in the Flightline Area. Following is a discussion of the aquifer test methods.

2.5.1 Slug Tests

Slug tests were performed in 13 monitor wells (LF04-4A, -4B, -4D, -4E, -4G, LF05-5A, -5B, -5C, -5D, -5E, FT09-12A, -12B, and -12C) at the Flightline Area, and results were used to calculate the hydraulic conductivity of the Upper Zone Aquifer. The wells selected for slug testing represent a range of hydrogeologic conditions.

The slug test evaluates the response of water levels in a well when a "slug" (known volume) of water is instantaneously removed or added. Typically, the response of the water level in a moderately permeable formation, such as the Upper Zone at Carswell AFB, is quite rapid. By determining the behavior of the water level in the well in response to the stress of the slug, the hydraulic conductivity of the aquifer material directly adjacent to the well screen can be calculated. To perform these calculations, the geometry of the well, aquifer boundary conditions, and initial water level must be known. The hydraulic conductivities were calculated using the method developed by Bouwer and Rice (1976).

The first step of the slug test was to measure the static water level in the well. Next, a known volume of water was removed by bailing and segregated for use as the slug. After the desired volume of water was removed from the well, a pressure transducer and attached cable were lowered into the well and suspended at a point just above the bottom of the well screen. The pressure transducer was connected to an In-Situ, Inc. Hermit 1000B automatic data logger, capable of measuring and recording pressure changes on a logarithmic frequency, beginning every 0.2 seconds in the first few seconds of the test. Before introducing the slug, the water level in the well was allowed to return to static conditions. Then, as the slug was rapidly poured in the well, the data recorder was activated to measure the response of the water level. At least two slug tests were conducted at each well tested to determine the reproducibility of the results.

2.5.2 Aquifer Pumping Test

An aquifer pumping test was performed to evaluate the hydraulic characteristics of the Upper Zone deposits in the Flightline Area. One 6-inch diameter well (LF04-03) was installed during field activities performed under D.O. 4 Modification 0004 to accommodate the 4-inch submersible pump used in the test. The pumping well was constructed of Schedule 80 PVC (slot size 0.020 inches) and was screened over the entire saturated thickness of the Upper Zone. In order to measure the aquifer's response to pumping, a 2-inch diameter observation well (LF04-02) was also installed. The observation well was installed about 50 feet north of the pumping well and was also screened over the entire saturated thickness of the Upper Zone. All other construction details were the same as for the Upper Zone monitor wells.

Pumping tests usually provide the means to stress an aquifer to such a degree that reliable estimates of transmissivity, storativity, and hydraulic conductivity can be made. These values are calculated using drawdown and recovery data recorded in the pumping well and observation wells. Each of these calculated parameters can ultimately be used to estimate groundwater flow rates and contaminant plume migration.

Step Pumping Test

Prior to the start of the pumping test, a step test was performed to assess aquifer response at multiple incremental pumping rates to determine the optimum pumping rate for the aquifer test. The optimum pumping rate for the Flightline Area pumping test was determined to be the full capacity of the submersible pump (Gould 1/2 HP, Model 10 EJ) or approximately 20 gallons-per-minute (gpm). The pump was rated at approximately 25 gpm with the amount of hydraulic head encountered in the pumping well. However, travel of discharge water through over 300 feet of polyethylene pipe before ultimate discharge to the City of Fort Worth sewer system reduced discharge rates because of friction losses. Background water-level data in the pumping well and the near observation well were collected electronically (at 10 minute intervals) with a Hermit brand model SE1000B data logger for approximately 40 hours prior to the step test. The background data are useful for defining natural trends (i.e., variability) in the Upper Zone Aquifer water level, such as increases from recharge or decreases due to evapotranspiration. The background data can also be useful in preventing misinterpretation of a water level decline as being caused by pumping, rather than by natural factors.

Pumping Test

The pumping test was conducted on 21 and 22 June 1990, and ran for 20 hours. The pumping test began about 16 hours after the end of the step test, when the measured water levels had recovered to over 99 percent of their pre-step test levels. The 4-inch submersible pump (used in the pump and step test) was powered by a 3500 watt portable generator. Pump test discharge water underwent aeration before being discharged to the City of Fort Worth sewer system, with air for the aeration provided by a portable 125 cfm air compressor. During the step and pump tests, the pumping rate was determined by timing discharge into a 5-gallon container with a stopwatch. All required data from the aquifer test were recorded on IRPIMS Pump/Recovery Test Data Collection Forms, included in Appendix F.

Because drawdown is more rapid at the beginning of a pumping test, electronic recording of water levels (in the pumping well and nearest observation well) was in a logarithmic progression. Manual water level measurements of seven additional Upper Zone monitor wells were also made at more frequent intervals during the early stages of the test. During the test, pH, conductivity, temperature and the visual characteristics of the discharge water were recorded at regular intervals. In addition, the pumping rate and drawdown of the pumping well were periodically checked to ensure consistency throughout the test, as wells will typically show a slow decline in discharge with time as drawdown increases.

Electronic data logging equipment was periodically downloaded by hand during the test. This allowed for construction of time-drawdown plots, or hydrographs, in the field for all wells being monitored during the test. These plots were used for preliminary determination of aquifer characteristics. Discharge water was pumped into a temporary holding tank to allow observation of water characteristics and recording of water quality data. Periodically during the pump test, water samples going into the holding tank (pre-aeration) and exiting the holding tank (post-aeration) were collected. These samples were collected in 40 mL VOA vials, filling each approximately two-thirds full with water. These water samples were allowed to sit in the direct sunlight for several hours prior to a headspace analysis for volatile organic content. During the time spent in the sunlight, volatile organics in the ground-water volatilized to the overlying air column. The volatile organic content of the headspace was measured with an HNu photoionization detector (PID). This was accomplished by cutting a small slit in the Teflon™ septum in the cap of the vial and quickly inserting the probe of the HNu PID. Comparison of the pre-aeration and post-aeration volatile organic concentrations allowed for gross determination of the aeration system efficiency.

At the conclusion of the 20-hour ground-water pumping period, water level monitoring and observations continued during the recovery period. Recovery data were included on the hydrographs for each well. Data from the aquifer pumping test were used to calculate hydraulic parameters for the Upper Zone Aquifer.

A more complete description of the aquifer pumping test procedures and methods of analysis is provided in Appendix F.

2.6 Surveying

Land surveying activities were conducted by Brittain & Crawford, Inc., Registered Land Surveyors, of Fort Worth. These activities consisted of measurements of the horizontal location of wells, boreholes, hand-auger holes, and surface water sampling locations in terms of State Plane Coordinates; and of measurements of reference point elevations to an accuracy of $\pm$ 0.01 foot. The survey was conducted to an accuracy needed for a second order survey. All of the data were provided as values posted on a map, and in tabular form (Appendix E).

3.0 PHYSICAL CHARACTERISTICS OF THE FLIGHTLINE AREA

This section describes the physical characteristics of the Flightline Area, with respect to local surface features, surface water bodies, geology, and ground-water occurrence. The primary basis of this characterization is interpretation of field and laboratory data obtained from the Installation Restoration Program (IRP) at Carswell AFB, Texas. Radian maintains a database containing all environmental data from the Flightline Area developed during the Phase II Stage 2 field program using the U.S. Air Force required Installation Restoration Program Information Management System (IRPIMS) format.

3.1 Topographic Surface Features

The area in the vicinity of the flightline ranges from an essentially level surface near the main (north-south) runway to gently rolling land near tributaries of Farmers Branch at the golf course. Figure 3-1 shows the location of the various surface features associated with the Flightline Area (buildings, roads, IRP sites, surface water bodies, etc.).

The Soils Conservation Service has identified four soil associations at Carswell AFB, however, only the Sanger-Purves-Slidell association occurs in the Flightline Area (USDA, 1981). The Sanger-Purves-Slidell soils range in thickness from 8-80 inches and are predominantly composed of clay loam. These are nearly level to gently sloping clayey soils with a permeability ranging from $<4.2 \times 10^{-5}$ to 3×10^{-4} cm/sec (ibid.).

All of the land is underlain by terrace deposits of the Trinity River and fill material associated with the construction of the base runway and taxiways. The terrace deposits have been moderately dissected by tributaries of Farmers Branch. Elevations in the area range from approximately 625 feet mean sea level (MSL) at Landfill 3 (LF03) to 580 feet MSL at the northern end of Landfill 5 (LF05) and at Site 11 (FT08).

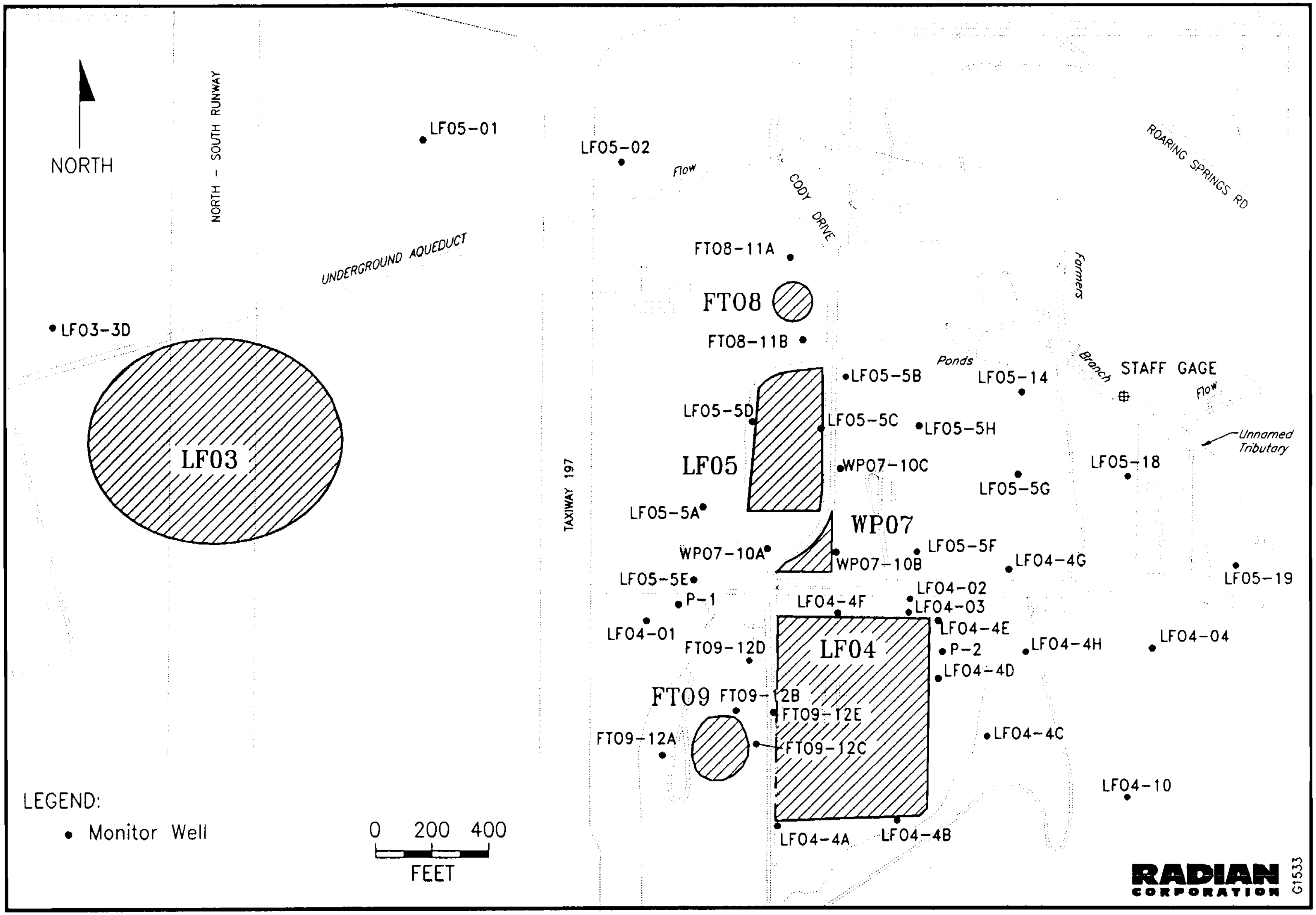

Figure 3-1. Prominent Surface Features in Flightline Area, Carswell AFB, Texas

3.2 Surface Water

The main surface water bodies in the Flightline Area are Farmers Branch, an unnamed tributary that flows into Farmers Branch, and two ponds on the Carswell AFB golf course (Figure 3-1). Surface drainage in the Flightline Area is generally to the north and east toward Farmers Branch. During the Stage 2 investigation performed in 1990, water was present in tributaries to Farmers Branch at 1) the southwest side of Landfill 4 (LF04), 2) the eastern side of Landfill 5 (LF05) and Fire Department Training Area 2 (FT09), and 3) the eastern edge of the Flightline Area (see unnamed tributary, Figure 3-1). Southwest of Landfill 4 (LF04), the unnamed tributary flows over limestone and shale outcrop, but becomes an influent stream as water percolates into terrace (Upper Zone) deposits south and east of the landfill. The tributary west of Landfill 5 (LF05) and Site 12 (FT09) becomes effluent at Cody Drive where terrace deposits are relatively thin. Farmers Branch ultimately discharges to the Trinity River, located on the eastern boundary of Carswell AFB. The evaluation of ground-water flow at the Flightline Area suggests that the surface water bodies may receive ground-water inflow, and possibly contaminants associated with the ground water. A staff gage was installed in Farmers Branch (Figure 3-1) and professionally surveyed during the additional Stage 2 field activities. Synoptic ground-water and surface water-level measurements made in June 1990 were used to evaluate Upper Zone ground-water/surface water communication. A detailed discussion of this communication is provided in Section 4 (Nature and Extent of Contamination) of this report.

Estimates of flow volume in Farmers Branch and the unnamed tributary were made. Flow volumes were calculated by measuring the width and estimating the average depth of the stream(s), then multiplying the resulting cross-sectional area by the estimated flow rate. The flow rate was estimated by measuring the length of time required for a floating object to travel a known distance. Estimated flow volumes at the time of sampling (April, 1990) were approximately 6 cubic feet/second (cfs) for the four locations on Farmers Branch and approximately 0.2 cfs for the unnamed tributary. Water in the two ponds appeared stagnant at the time of sampling. Observed flow in Farmers

Branch during field activities was extremely variable, ranging from <5 to >100 cfs (following heavy rains).

3.3 Geology

Carswell AFB is located on the relatively stable Texas craton, west of the faults that lie along the Ouachita Structural Belt. No major faults or fracture zones have been mapped near the base. The regional dip of the rocks beneath Carswell AFB is between 35 and 40 feet per mile in an easterly to southeasterly direction. From youngest to oldest, the major geologic formations found in the Flightline Area of Carswell AFB are as follows: 1) Quaternary Alluvium, 2) Cretaceous Goodland Limestone, 3) Cretaceous Walnut Formation, 4) Cretaceous Paluxy Formation, 5) Cretaceous Glen Rose Formation, and 6) Cretaceous Twin Mountains Formation.

Subsurface geologic conditions in the Flightline Area were characterized using indirect methods (geophysical surveys) and direct subsurface sampling and lithologic logging during drilling operations. Most of the IRP activities focused on the Upper Zone. The Goodland/Walnut Aquitard and the Paluxy Aquifer in the Flightline Area were the deepest (oldest) units penetrated, and by only two monitor wells installed during the initial Stage 2 effort. The following subsections contain discussions of the geology in the Flightline Area.

3.3.1 Quaternary Alluvium

Quaternary alluvium, deposited by the Trinity River, is found at the surface throughout the Flightline Area site, as well as over most of the base. The alluvium consists of floodplain and fluviatile terrace deposits of gravel, sand, silt, and clay that occur as a veneer on the eroded surface of the Goodland Limestone. The unconsolidated alluvial deposits and fill are referred to as the "Upper Zone," a term initially applied to similar alluvial deposits at AF Plant 4 (Hargis and Montgomery, Inc., 1983). The Upper Zone is a hydrogeologic unit at Carswell AFB that is a mixture of clay, silt, sand, and gravel of variable thickness and degree of saturation.

Drilling on the base indicates that the alluvial deposits (and fill) range from a few feet to greater than 45 feet of interbedded clay, silt, sand, and gravel. The irregular thickness of the alluvium is due to depositional events, stream channeling, and erosion. In general, silt and clay with variable amounts of sand and gravel occur at the land surface down to depths of five to 10 feet. Underlying the silt and clay is a sand and gravel unit that normally increases in grain size with increasing depth. These strata appear to be relatively continuous across the area of investigation, although coarse gravel deposits occur in limited areas generally east of the Fire Department Training Areas 1 (FT08) and 2 (FT09). The sand deposits are fine-grained to coarse-grained, tan to rust in color, and composed predominantly of quartz grains. Gravel is mostly limestone and shell fragments ranging in size from fine gravel to cobbles. A sand and gravel isopach map of the Flightline Area is presented in Figure 3-2.

During the most recent drilling activities in the Flightline Area, efforts were made to characterize the paleochannels (old stream channel patterns) believed to exist in the area. Examination of Figure 3-2 shows thick sand and gravel sequences, indicative of channel deposits, to occur east of Taxiway 197 and roughly paralleling White Settlement Road. Sand and gravel thicknesses greater than 20 feet occur in an approximately 800 feet-wide area, with White Settlement Road serving as the approximate median to the pattern. Additional evidence of the channel pattern is seen in the eroded nature of the bedrock in this area and the extensive limestone gravels (scoured bedrock). The gravels were deposited as channel lag deposits on the scoured upper surface of the underlying bedrock (Goodland/Walnut Formations).

3.3.2 Cretaceous Goodland Limestone and Walnut Formation

Underlying the alluvium are the Cretaceous-age Goodland and Walnut Formations. Both formations consist of interbedded, fossiliferous, hard limestone and calcareous shale, and are thus discussed together. The rock is fractured and there is considerable jointing and flaking, which gives the limestone a fractured appearance. These strata are generally dry, although small amounts of water are occasionally present in the shale and clay units.

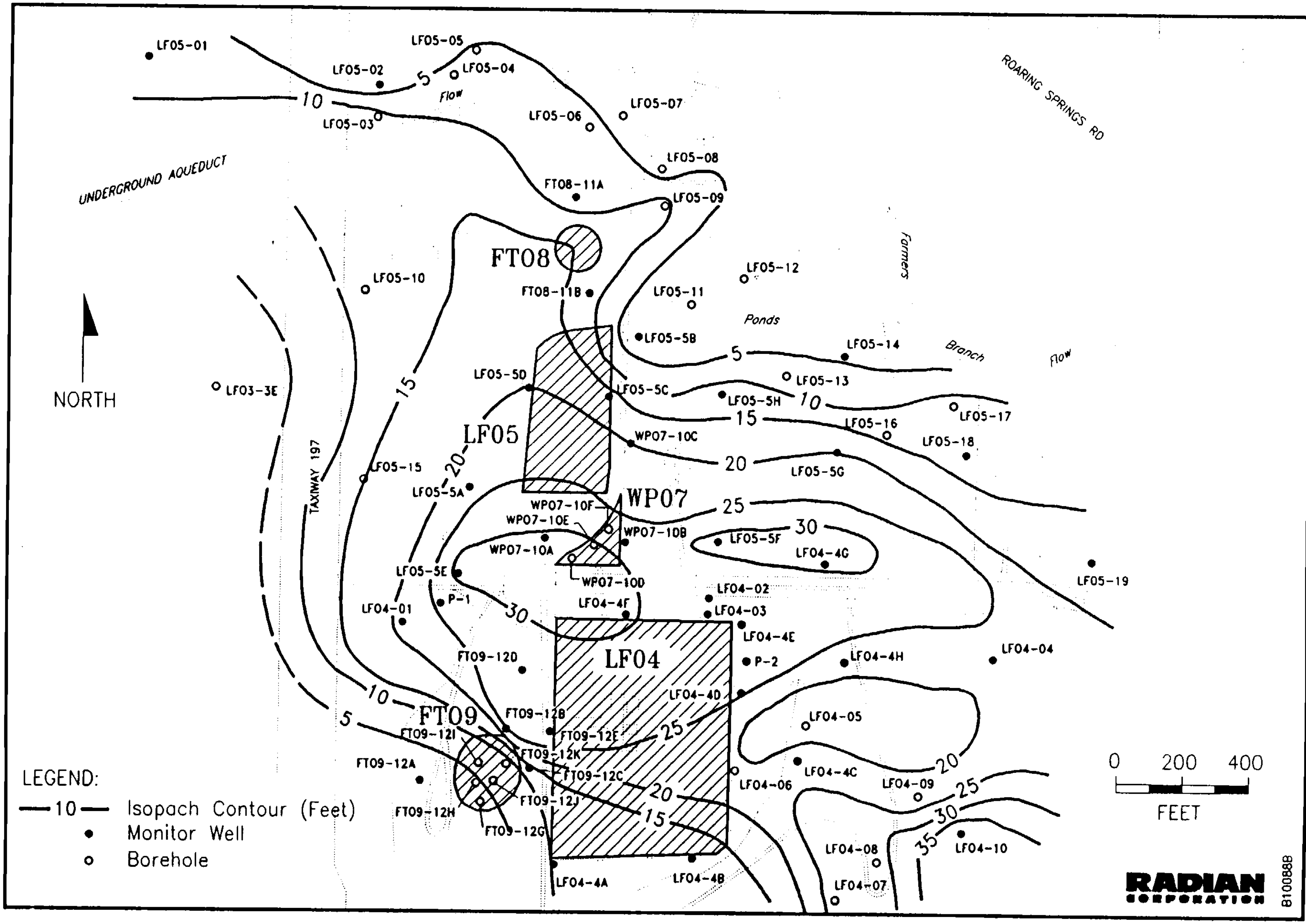

Figure 3-2. Sand and Gravel Isopach Map, Flightline Area, Carswell AFB, Texas

The erosional surface of the bedrock is generally level across most of the Carswell AFB area, with a pronounced rise in the southwest portion of the base corresponding to the outcrop of limestone and shale. Table 3-1 shows the depth (and corresponding elevation) to bedrock (Goodland/Walnut Formation) at all drilling locations in the Flightline Area. Figure 3-3 is a contour map of the elevation (MSL) of the top of the bedrock surface. The locally irregular topography of the top of the bedrock is characteristic of an erosional surface modified by fluvial processes, which is recorded by the overlying sequence of interbedded fluviatile gravel, sand, silt, and clay.

The thickness of the Goodland/Walnut Formations, as observed during the drilling of Paluxy wells P-1 and P-2 (Figure 3-1), is approximately 30-40 feet beneath the Flightline Area. However, because the top of the Goodland/Walnut Formations is an erosional surface, the thickness in isolated areas may be less than originally deposited. It has been reported that the Quaternary alluvium and the Cretaceous Paluxy Formation are in direct contact at the eastern boundary of AF Plant 4, where the Goodland/Walnut Formations were completely eroded away (Hargis and Associates, 1985).

3.3.3 Cretaceous Paluxy Formation

Beneath the Goodland and Walnut Formations lies the Cretaceous-age Paluxy Formation, often referred to as the Paluxy Sand. The Paluxy Formation is the deepest unit penetrated in the Flightline Area during the IRP efforts. Regionally, the Paluxy Sand is divided into upper and lower sand members by an intervening shale unit. The sands in the upper part of the Paluxy are reported by drillers to be fine-grained and shaley. The lower sand member generally consists of two separate and distinct sand strata, but the individual sand beds do not maintain constant thickness or lithology over long distances. About one-half to three-fourths of the Paluxy is sand; the remainder consists of clay, sandy clay, shale, lignite, silicified wood fragments, and nodules of pyrite. In general, coarse-grained sand is in the lower part of the Paluxy which grades upward into fine-grained sand with variable amounts of shale and clay.

TABLE 3-1. ELEVATION OF BEDROCK IN FLIGHTLINE AREA, CARSWELL AFB, TEXAS

Location ID	Ground Level Elevation (Ft, MSL)	Depth to Bedrock (Ft)	Elevation of Bedrock (Ft, MSL)	Sand and Gravel Thickness (Ft)
LF03-3A	633.47	18.0	615.5	0
LF03-3B	633.84	19.5	614.3	0
LF03-3C	635.39	12.0	623.4	0
LF03-3D	621.6	15.0	606.6	0
LF03-3E	622.87	16.0	606.9	0
LF04-4A	624.6	18.0	606.6	11.0
LF04-4B	618.4	17.5	600.9	10.0
LF04-4C	610.9	29.0	581.9	23.0
LF04-4D	613.1	29.0	584.1	25.0
LF04-4E	617.5	33.5	584.0	28.0
LF04-4F	622.8	>35.5	<587.3	>29.5
LF04-4G	619.1	39.5	579.6	30.5
LF04-4H	610.5	27.0	583.5	23.0
LF04-01	626.5	40.0	586.5	20.7
LF04-02	621.0	37.0	584.0	26.0
LF04-03	620.5	37.5	583.0	25.4
LF04-04	609.4	25.0	584.4	23.5
LF04-05	608.8	25.8	583.0	17.0
LF04-06	613.3	29.5	583.8	24.1
LF04-07	630.4	38.2	592.2	28.4
LF04-08	630.0	47.0	583.0	38.9
LF04-09	627.4	47.0	580.4	37.4
LF04-10	626.9	49.0	577.9	36.3
LF05-5A	619.4	31.0	588.4	13.5
LF05-5B	597.4	8.0	589.4	3.0
LF05-5C	606.8	21.0	585.8	16.0
LF05-5D	608.5	24.0	584.5	20.0
LF05-5E	623.9	>40.0	<583.9	>31.0
LF05-5F	619.4	>37.0	<582.4	>33.0
LF05-5G	612.0	29.0	583.0	21.0
LF05-5H	608.4	25.0	583.4	11.0
LF05-01	619.3	25.0	594.3	6.9
LF05-02	620.0	27.0	593.0	2.1
LF05-03	620.6	27.4	593.2	12.2
LF05-04	617.3	28.0	589.3	5.3
LF05-05	616.1	26.0	590.1	6.0
LF05-06	598.3	7.0	591.3	6.5
LF05-07	598.0	5.8	592.2	4.0
LF05-08	606.8	14.5	592.3	2.5
LF05-09	604.9	14.0	590.9	10.5

(continued)

TABLE 3-1. (Continued)

Location ID	Ground Level Elevation (Ft, MSL)	Depth to Bedrock (Ft)	Elevation of Bedrock (Ft, MSL)	Sand and Gravel Thickness (Ft)
LF05-10	623.9	36.0	587.9	12.0
LF05-11	597.6	10.0	587.6	3.0
LF05-12	594.4	9.0	585.4	0.5
LF05-13	605.0	17.0	588.0	7.7
LF05-14	603.2	13.0	590.2	4.8
LF05-15	626.5	40.5	586.0	15.0
LF05-16	612.3	23.0	589.3	14.0
LF05-17	606.5	16.5	590.0	12.0
LF05-18	612.1	23.2	588.9	12.2
LF05-19	606.3	20.5	585.8	17.7
WP07-10A	624.2	>39.0	<585.2	26.5
WP07-10B	621.1	33.0	588.1	27.0
WP07-10C	615.4	31.0	584.4	20.0
WP07-10D	623.3	>29.0	<594.3	>13.0
WP07-10E	622.5	>29.0	<593.5	>17.0
WP07-10F	621.5	>29.0	<592.5	>20.0
FT08-11A	604.8	13.5	591.3	9.5
FT08-11B	603.8	14.0	589.8	11.0
FT09-12A	632.0	18.0	614.0	7.0
FT09-12B	625.6	39.0	586.6	26.0
FT09-12C	625.5	31.0	594.5	15.0
FT09-12D	624.8	>36.0	<588.8	>21.0
FT09-12E	624.5	39.0	585.5	26.0
FT09-12G	629.2	--	--	--
FT09-12H	629.1	25.0	604.1	6.0
FT09-12I	629.2	24.0	605.2	5.0
FT09-12J	628.7	23.0	605.7	4.0
FT09-12K	626.7	>25.0	<601.7	>5.0

-- Not Determined

MSL - Mean Sea Level

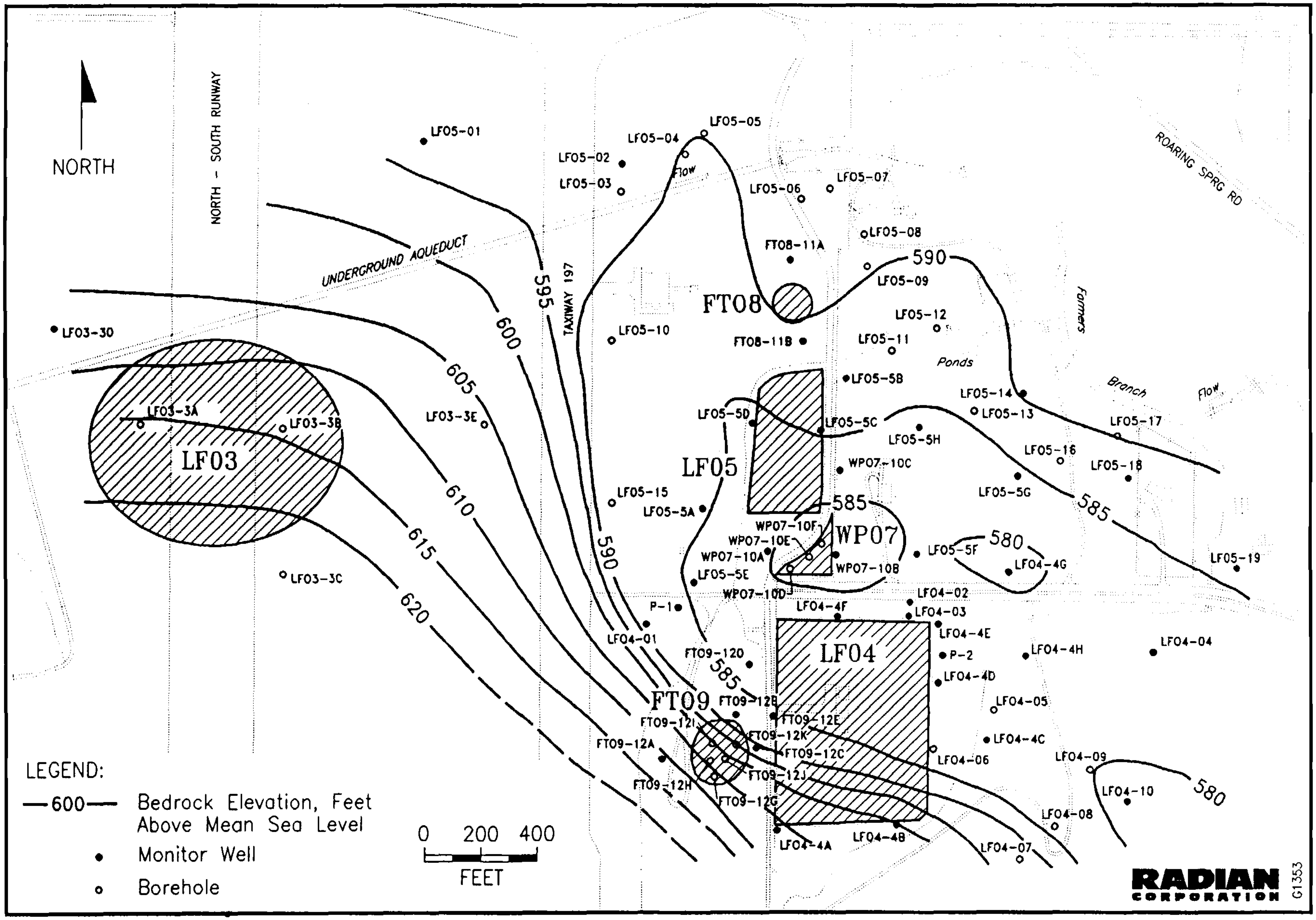

Figure 3-3. Contoured Elevation of Bedrock Surface in Flightline Area, Carswell AFB, Texas

In the two Paluxy monitor wells (P-1 and P-2) installed during the initial Stage 2 effort, drilling progressed through the upper sand member to the intervening shale unit. The upper sand member ranged from 30 to 35 feet in thickness and consisted of varying amounts of sand, sandstone, clay, and shale. The shale unit separating the upper and lower Paluxy "sands" was encountered at approximately 105 feet, below land surface in both P-1 and P-2.

3.3.4 Cretaceous Glen Rose Formation

Underlying the Paluxy Sand is the Glen Rose Formation, which represents the seaward facies of part of the Twin Mountains Formation, being deposited simultaneously to the north. The Glen Rose was not penetrated during drilling in the Flightline Area, but typically consists primarily of calcareous sedimentary rocks (limestone) and some sands, clays, and anhydrite.

3.3.5 Cretaceous Twin Mountains Formation

The Twin Mountains Formation, with the Glen Rose Formation capping it, is the oldest Cretaceous-age formation reported in the vicinity of Carswell AFB. In ascending order, the Twin Mountains Formation is divided into the Sycamore Sand Member, the Cow Creek Limestone Member, and the Hensell Sand Member. The Twin Mountains Formation does not crop out in Tarrant County. The Twin Mountains Formation consists of a basal conglomerate of chert and quartz, grading upward into coarse- to fine-grained sand interspersed with varicolored shale.

3.3.6 Flightline Area Cross-Sections

Following the recent drilling activities at the Flightline Area, six geologic cross-sections were constructed, showing borehole lithologies (as well as the static water levels in the Upper Zone measured on 18 June 1990). A location map for the newly constructed cross-sections through the site is provided in Figure 3-4.

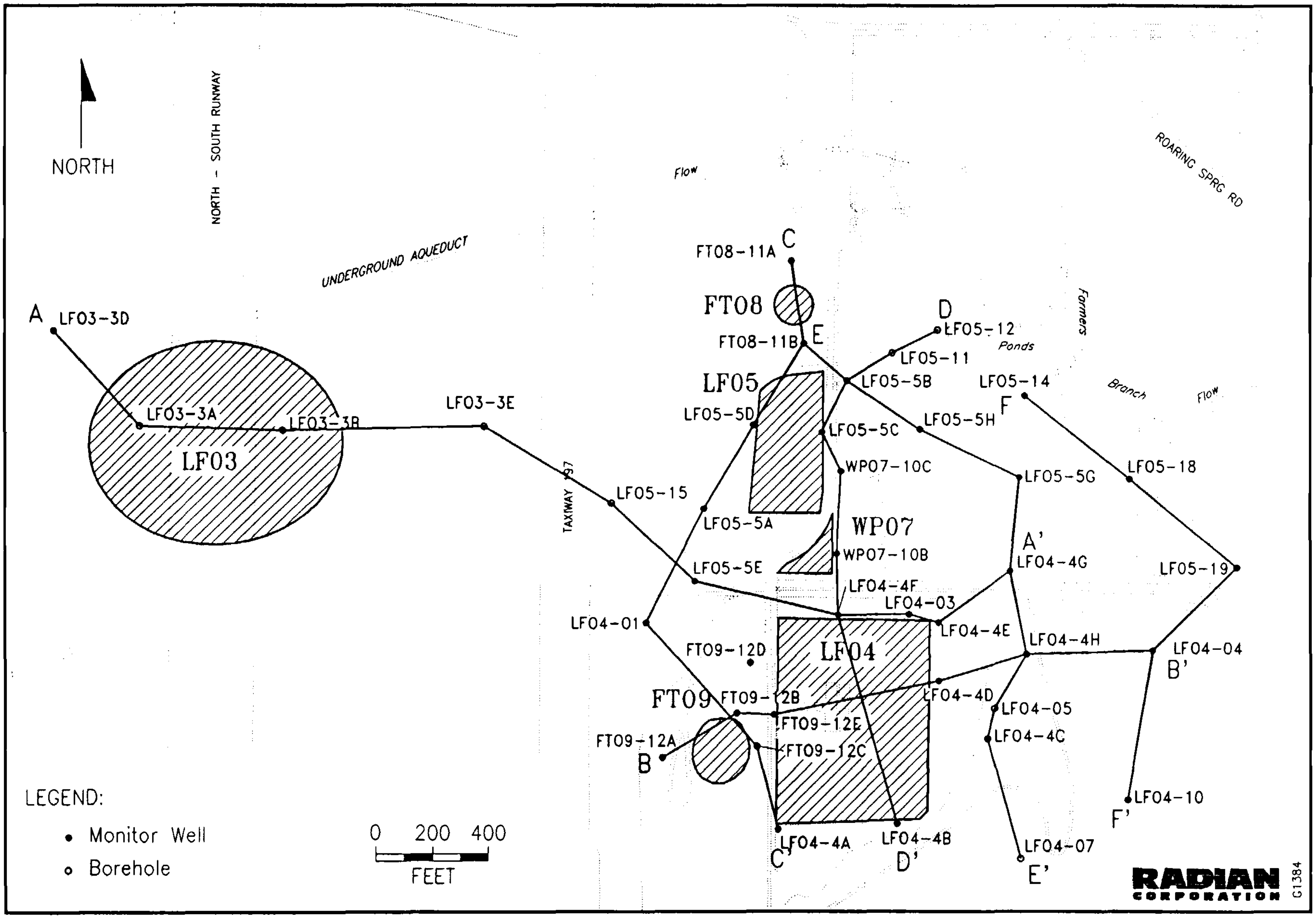

Figure 3-4. Location Map for Geologic Cross-Sections Through the Flightline Area, Carswell AFB, Texas

Two of the cross-sections (A-A' and B-B') are oriented roughly west-east and the remaining four are oriented roughly north-south (C-C' through F-F') through the site. All of the cross-sections intersect the relatively thick sand and gravel sequence observed at the site (Figure 3-2).

Cross-section A-A' (Figure 3-5) depicts the subsurface from the Landfill 3 (LF03) area to the area just east of Landfills 4 (LF04) and 5 (LF05) and the Waste Burial Area (WP07). An important feature in this cross-section is the lack of sand and gravel in the borings completed in the Landfill 3 area. There is a steep incline in the upper surface of the bedrock (Goodland/Walnut Formations) between borings LF03-3E and LF05-15. Coincident with the lower bedrock elevation in the vicinity of LF05-15 is the appearance of relatively thick sands and gravels of the Upper Zone. This cross-section is oriented through the thickest sands and gravels encountered in the Flightline Area (Figure 3-2). Boring locations from LF05-15 eastward all display a fining-upwards sequence in the Upper Zone deposits, which is consistent with alluvial deposition. The lower bedrock surface observed in the eastern half of the cross-section is probably the result of stream erosion, as rounded limestone and chert gravels (typical of channel lag deposits) rest directly on the bedrock surface. These deposits are believed to coincide with the location of a former channel (paleochannel) of what is now Farmers Branch.

In cross-section B-B' (Figure 3-6), another steep incline is observed in the bedrock topography between monitor well locations FT09-12A and FT09-12B. Paralleling the inclined bedrock surface is a steeply-dipping Upper Zone water table. Fining-upwards sequences of sediments are seen in all borings included in this cross-section, with gravels occurring on the eroded bedrock surface east of FT09-12A.

Shown in Figure 3-7 is cross-section C-C'. Gravels only occur in the middle area of the cross-section, with a relatively higher bedrock surface occurring in the northern and southern reaches of the section. The steeply inclined bedrock surface seen at location FT09-12A (B-B') is also reflected

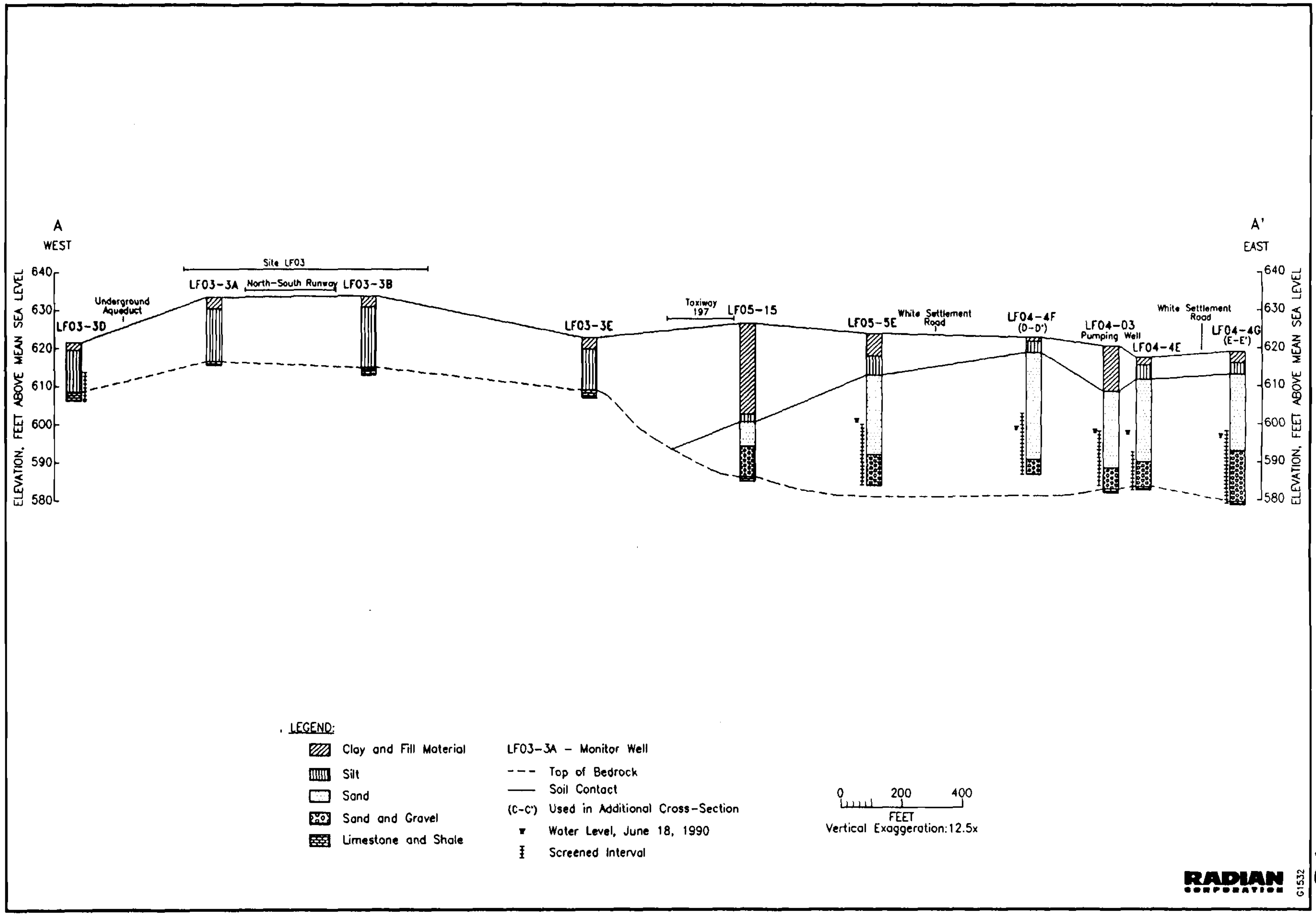

Figure 3-5. Geologic Cross-Section A-A', Flightline Area, Carswell AFB, Texas

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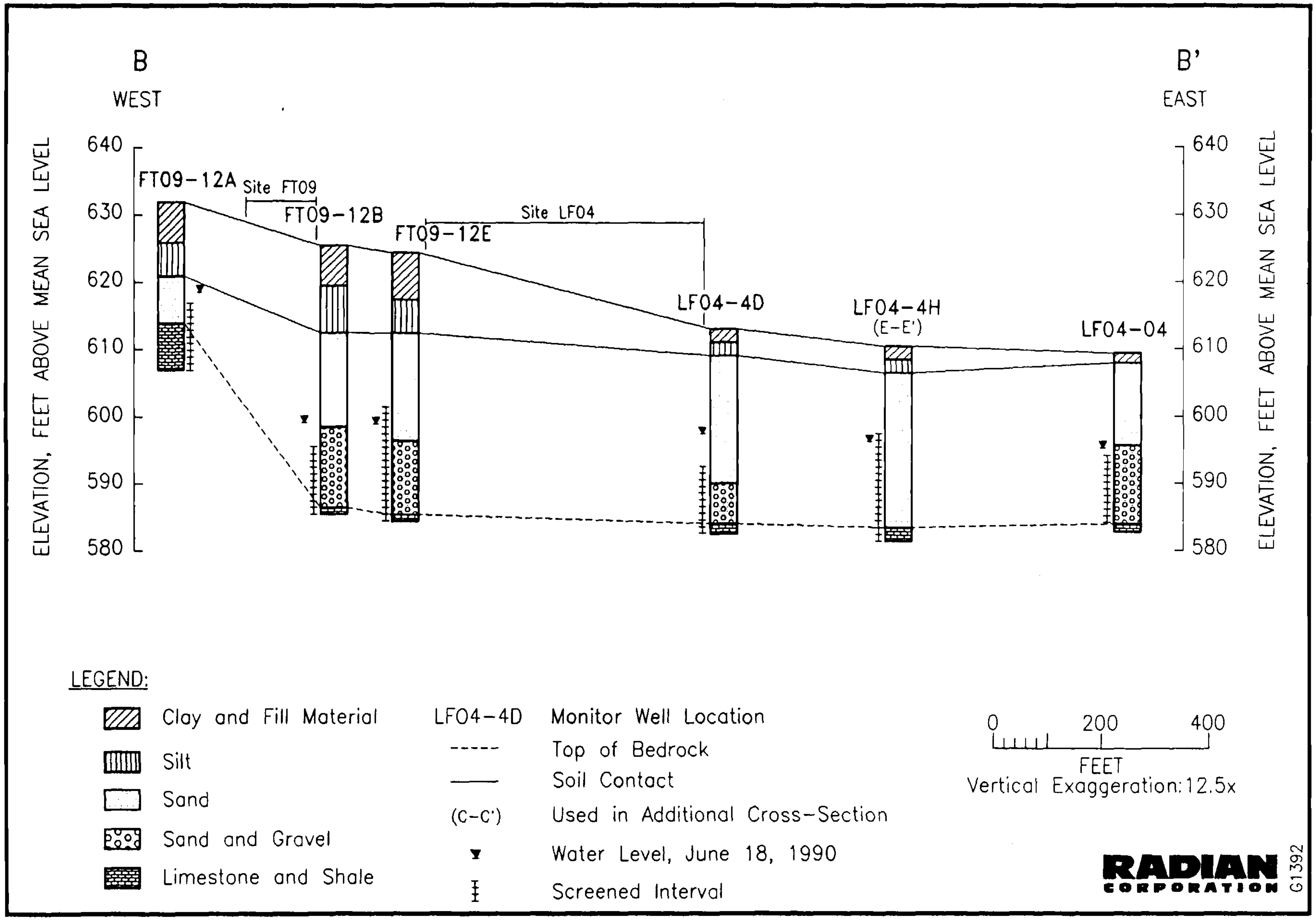

Figure 3-6. Geologic Cross-Section B-B', Flightline Area, Carswell AFB, Texas

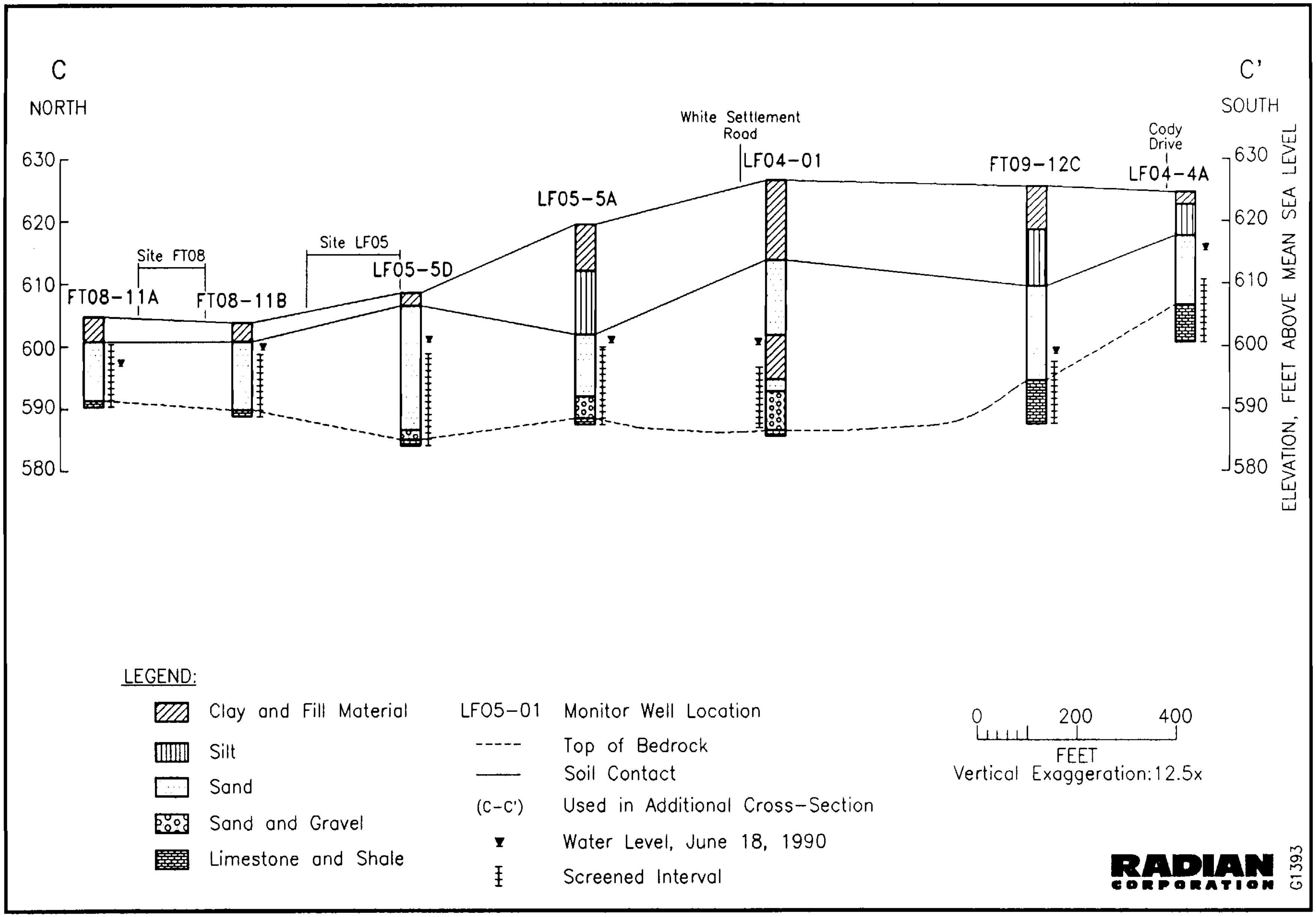

Figure 3-7. Geologic Cross-Section C-C', Flightline Area, Carswell AFB, Texas

on this cross-section at location LF04-4A. Monitor well FT09-12C occurs at approximately the southern edge of the paleochannel deposits observed in the Flightline Area.

Cross-section D-D' is shown on Figure 3-8. Again, a relatively thick sequence of coarse-grained materials occurs through the middle portion of the cross-section. Southward from boring LF05-12, the coarse-grained Upper Zone deposits thicken, with the thickest deposits occurring in the vicinity of LF04-4F. Monitor well LF04-4F is the only location on this section where gravels were found. Location LF04-4B, like LF04-4A (C-C'), is located on a relative high on the bedrock surface.

Geologic cross-section E-E' (Figure 3-9) shows the thickest sequence of Upper Zone sands and gravels occurring in the vicinity of LF04-4G. Monitor well LF04-4G occurs within the trend of the thickest Upper Zone sands and gravels observed in the Flightline Area. The trend axis is situated approximately on White Settlement Road.

The easternmost cross-section through the Flightline Area, F-F' (Figure 3-10), includes five newly installed ground-water monitor wells. Although monitor well boring LF04-10 encountered the thickest sequence of Upper Zone coarse-grained sediments, the potentiometric surface (derived from water-level measurements taken on June 18, 1990) indicates ground-water flow toward the location of LF05-19, rather than parallel to the depositional trend, as might be expected. In this area, the tendency for ground water to discharge to Farmers Branch apparently exerts a greater influence on the flow direction than the permeability of the Upper Zone sediments.

3.4 Hydrogeology

Five major hydrogeologic units exist beneath Carswell AFB. From shallowest to deepest they are: 1) an Upper Zone of unconfined ground water occurring within the alluvial terrace deposits associated with the Trinity River; 2) an aquitard of predominantly dry limestone of the Goodland and

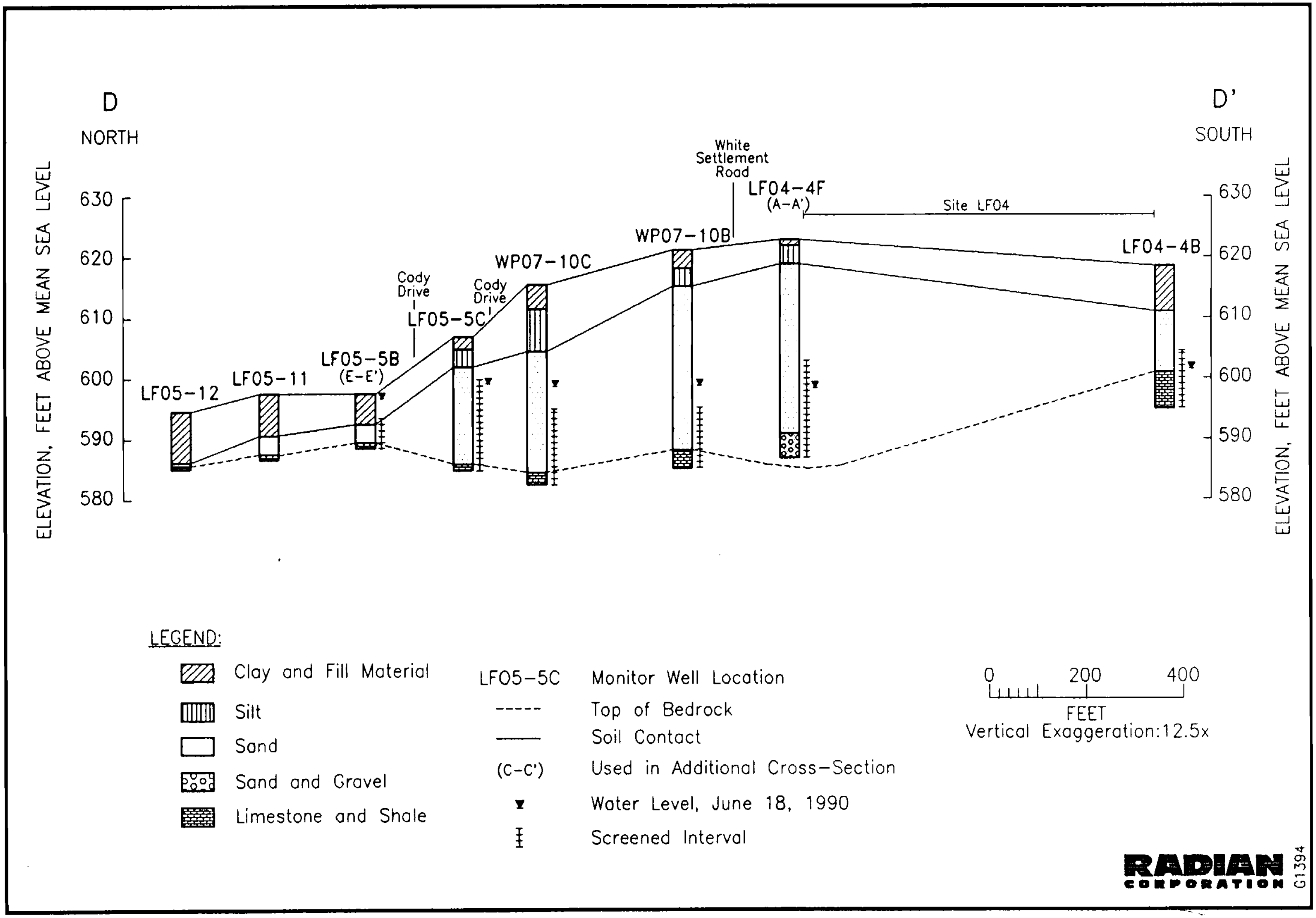

Figure 3-8. Geologic Cross-Section D-D', Flightline Area, Carswell AFB, Texas

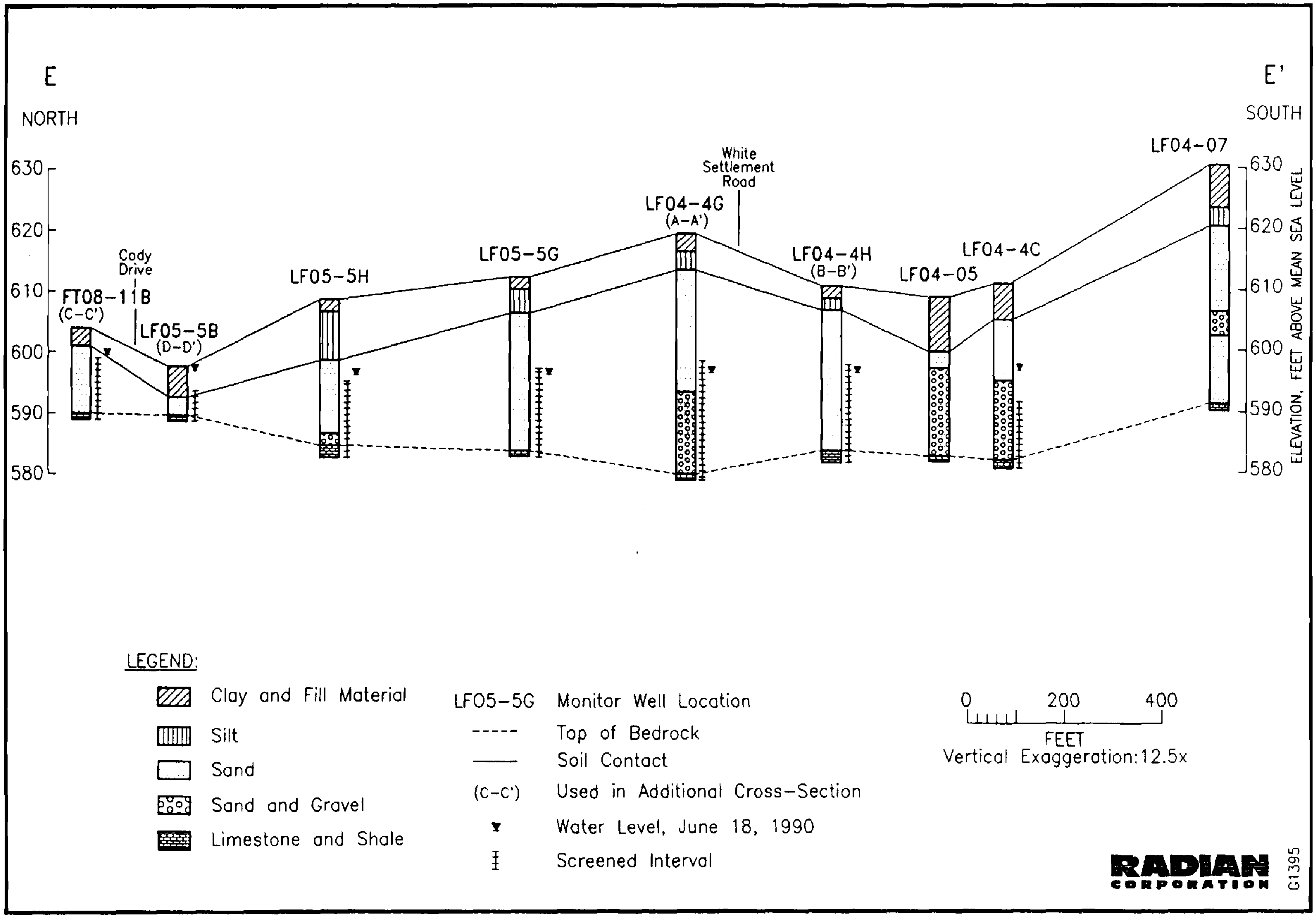

Figure 3-9. Geologic Cross-Section E-E', Flightline Area, Carswell AFB, Texas

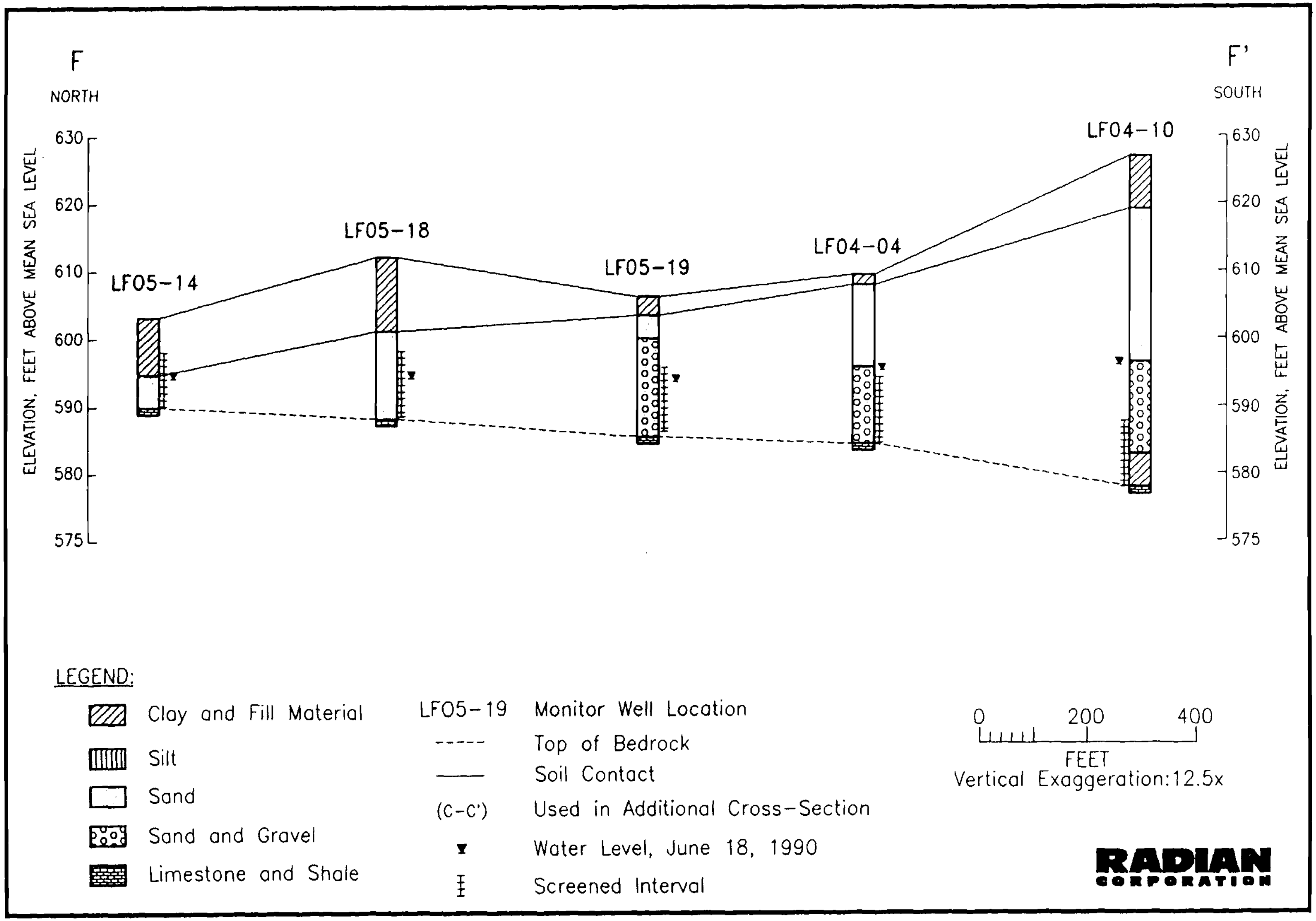

Figure 3-10. Geologic Cross-Section F-F', Flightline Area, Carswell AFB, Texas

Walnut Formations; 3) an aquifer in the Paluxy Sand; 4) an aquitard of relatively impermeable limestone in the Glen Rose Formation; and 5) a major aquifer in the sandstone of the Twin Mountains Formation. Only the first three units were investigated in the Flightline Area during the IRP, with the primary focus being on the Upper Zone. The Upper Zone was the only unit studied in this most recent Stage 2 (1990) effort. Figure 3-11 shows the general depth of occurrence and thickness of each of the major hydrogeologic units expected in the Flightline Area. Descriptions and properties of the hydrogeologic units are summarized in Table 3-2. The following subsections present the hydrogeologic characteristics of each unit based on field data and literature sources.

3.4.1 Upper Zone Aquifer

The Upper Zone ground water occurs within the alluvial deposits at Carswell AFB. Low permeability is typical of this alluvium because of the large amounts of clay and silt. However, there are zones of greater permeability in the sands and gravels of former channel deposits. Recharge to the water-bearing deposits is local, from rainfall and infiltration from stream channels and drainage ditches. The direction of ground-water flow is generally controlled by the bedrock topography of the Walnut Formation.

3.4.1.1 Ground-Water Occurrence and Flow

Table 3-3 shows the results of the synoptic water-level survey performed on 18 June 1990. Figure 3-12 is the resulting potentiometric surface map of the Upper Zone Aquifer. Ground-water flow in the Upper Zone is generally northeastward, toward Farmers Branch, a tributary to the West Fork of the Trinity River.

From the outlet of Farmers Branch from the underground aqueduct (which conveys the stream under the Flightline) the stream flows over bedrock at the Goodland/Walnut Formation until it flows into the Trinity River on the eastern boundary of Carswell AFB. The Upper zone ground-water flow through

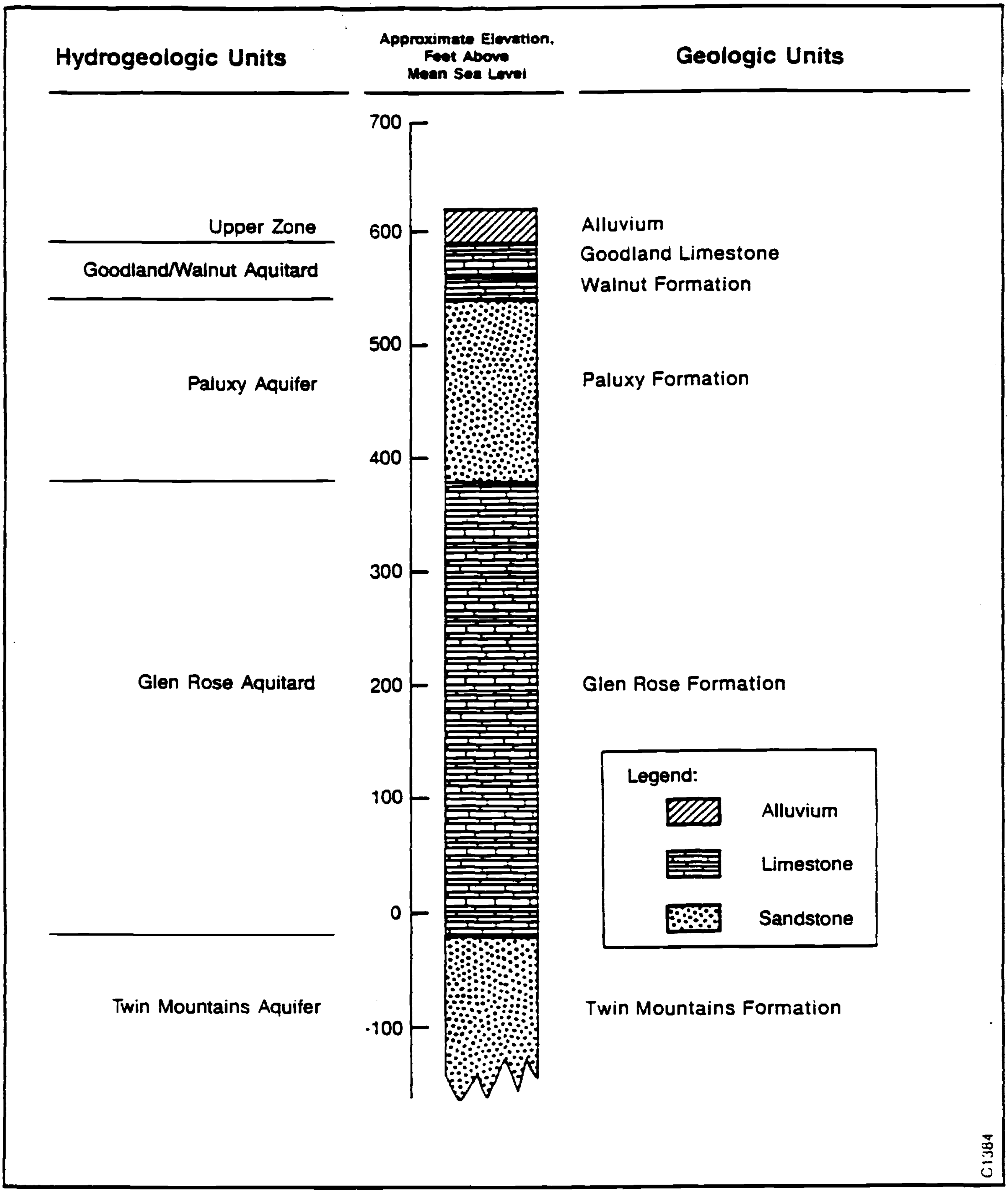

Figure 3-11. Generalized Hydrogeologic Units at Flightline Area, Carswell AFB, Texas

TABLE 3-2. GEOLOGIC FORMATIONS IN THE VICINITY OF CARSWELL AFB, TEXAS

System	Series and Group	Formation and Member	Thickness (ft)	Character of Rocks	Topographic Expression	Water-Bearing Properties
Quaternary	Recent and Pleistocene	Alluvium	0-45	Sand, gravel, clay, and silt.	Terrace and flood-plain deposits.	Small to moderate yields. Water unsatisfactory for use unless treated.
Cretaceous	Comanche Series Washita Group	Duck Creek Formation	0-90	Impure limestone and marl, which is blue when fresh and straw-colored when weathered. Fossiliferous with distinctive ammonites.	Bench topography produced by lower limestone unit. Upper marl forms slope separating the Duck Creek from Fort Worth limestone.	Small to moderate yields. Water unsatisfactory for use unless treated.
	Comanche Series Fredericksburg Group	Kiamichi Formation	0-40	Blue and brownish-yellow marl, thin limestone and sandstone flags.	Grassy slope separating scarps of Goodland and Duck Creek Formations.	Small to moderate yields. Water unsatisfactory for use unless treated.
		Goodland Limestone	0-130	Chalky-white fossiliferous limestone, and blue to yellowish brown marl.	Prominent glaring-white escarpment along streams.	Small to moderate yields. Water unsatisfactory for use unless treated.
		Walnut Clay	0-28	Shell agglomerate fossiliferous clay and limestone, sandy clay, and black shale.	Forms conspicuous escarpment and waterfalls in western Cross Timbers belt.	Not known to yield water to wells in Tarrant County.
				UNCONFORMITY		
Cretaceous	Comanche Series Trinity Group	Paluxy Sand	140-190	Fine-grained sand, shale, sandy shale, lignite and pyrite.	Sandy soil, hummocky topography, heavily wooded with oaks.	Source of supply for most households, smaller cities, and some industries.
		Glen Rose Limestone	250-450	Fine-grained limestone, shale, marl, and sandstone.	Not exposed in Tarrant County.	Sands yield small supplies to wells in Fort Worth and western Tarrant County. Water too highly
mineralized east of Fort						Worth.
		Twin Mountains Formation (formerly Travis Peak Formation)	250-450	Coarse to fine-grained sandstone, red shale, red and yellow clay at	Not exposed in Tarrant County.	Principal aquifer in Tarrant County. Yields large supplies for base.
municipal and industrial						purposes. Water in upper sands east of Fort Worth may be highly mineralized.

Source: E. R. Legget (1957).

TABLE 3-3. RESULTS OF FLIGHTLINE AREA UPPER ZONE SYNOPTIC WATER LEVEL SURVEY CONDUCTED ON JUNE 18, 1990

Location ID	Time	Measuring Point Elevation (Ft, MSL)	Depth to Water (Ft)	Water Level Elevation (Ft, MSL)
LF04-01	1553	629.24	28.98	600.26
LF04-02	1738	623.68	26.23	597.45
LF04-03	1735	623.25	25.67	597.58
LF04-04	1756	612.07	16.75	595.32
LF04-10	1801	626.54	30.49	596.05
LF04-4A	1813	625.76	10.48	615.28
LF04-4B	1818	619.90	18.27	601.63
LF04-4C	1809	613.04	16.42	596.62
LF04-4D	1749	615.35	18.06	597.29
LF04-4E	1746	618.54	21.35	597.19
LF04-4F	1731	625.36	26.96	598.40
LF04-4G	1740	620.02	23.69	596.33
LF04-4H	1752	613.43	17.15	596.28
LF05-01	1545	621.96	18.14	603.82
LF05-02	1549	622.69	24.86	597.83
LF05-14	1700	602.98	8.84	594.14
LF05-18	1834	611.84	17.73	594.11
LF05-19	1650	606.08	12.54	593.54
LF05-5A	1618	623.18	22.67	600.51
LF05-5B	1708	600.45	3.73	596.72
LF05-5C	1627	608.68	9.56	599.12
LF05-5D	1624	611.71	10.98	600.73
LF05-5E	1615	626.89	26.60	600.29
LF05-5F	1721	618.95	21.83	597.12
LF05-5G	1714	615.39	19.31	596.08
LF05-5H	1711	610.62	14.54	596.08
FT09-12A	1557	635.66	17.10	618.56
FT09-12B	1603	627.55	28.38	599.17
FT09-12C	1601	628.05	29.23	598.82
FT09-12D	1611	627.45	28.13	599.32
FT09-12E	1606	627.48	28.68	598.80
FT08-11A	1634	608.22	11.23	596.99
FT08-11B	1630	608.14	8.63	599.51
WP07-10A	1620	626.70	26.68	600.02
WP07-10B	1728	624.46	25.63	598.83
WP07-10C	1726	617.24	18.59	598.65
Staff Gage	1840	579.44 (1.0 ft mark on gage)	0.57 (water reading on gage)	579.01

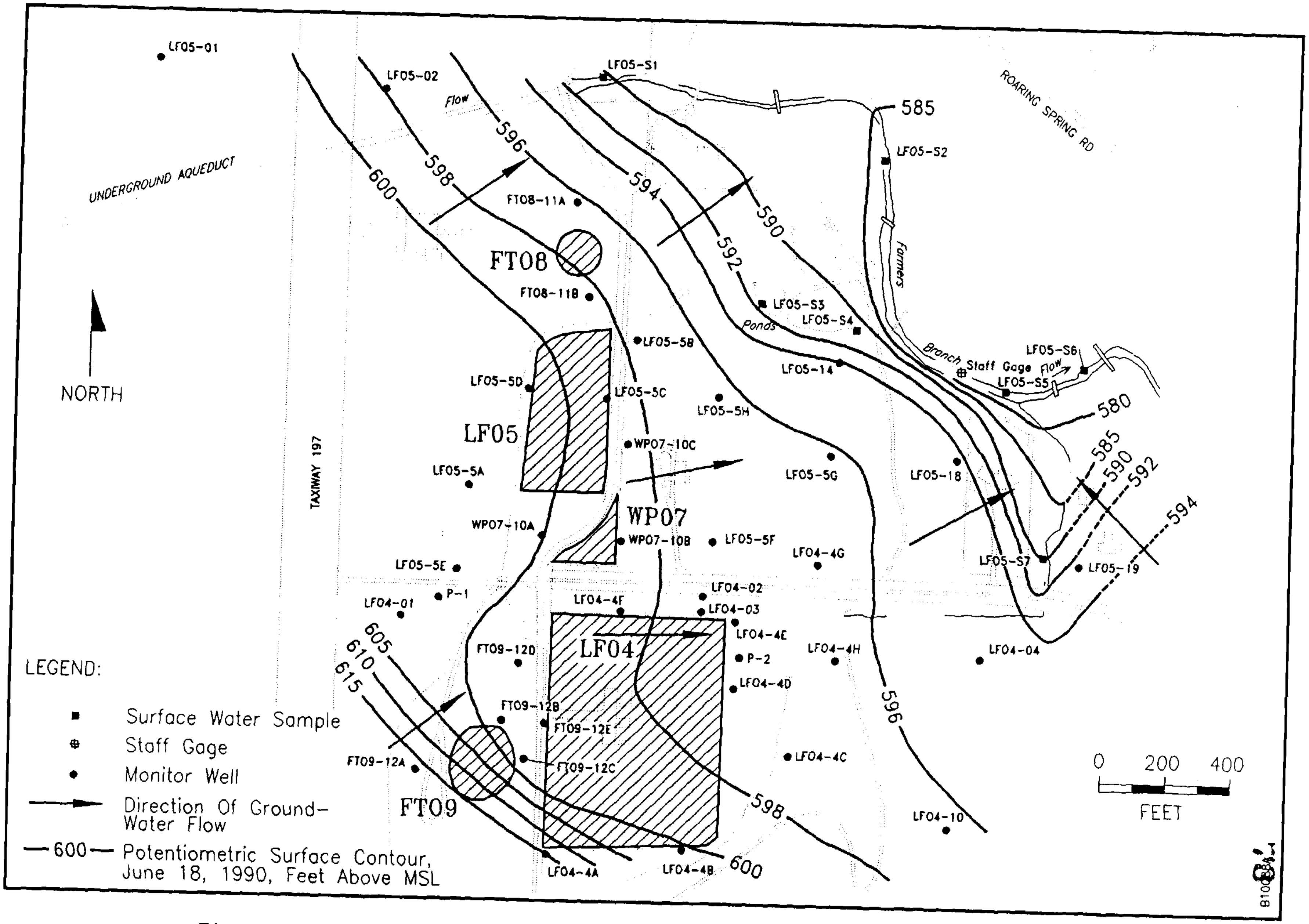

Figure 3-12. Potentiometric Surface Map of Upper Zone Aquifer, Flightline Area, Carswell AFB, Texas

the Flightline Area, being generally northeastward, intercepts Farmers Branch in the northern and northeastern portion of the Flightline Area site. The Upper Zone sediments, which are up to 40 feet thick in areas west and southwest of Farmers Branch, either thin to their eventual disappearance at the stream or are exposed as sheer cliffs (cut-banks) near the stream. Field reconnaissance revealed Upper Zone ground water seeping from the face of the exposed banks.

The potentiometric surface map (Figure 3-12) includes water level information from both the ground water and the surface water (surveyed at six locations along Farmers Branch). Farmers Branch is shown to be a point of discharge for ground water, as the Upper Zone hydraulic gradient is shown to be toward the stream.

The area north of Farmers Branch in the Flightline Area has not been investigated. However, visual observation has shown the area to be relatively flat in the vicinity of the stream. Upper Zone deposits are probably thin in this area. With Farmers Branch being a zone of ground-water discharge in the Flightline Area, Upper Zone ground-water flow in the area north of Farmers Branch would locally be toward the stream.

3.4.1.2 Hydraulic Characteristics of Upper Zone Aquifer

Slug tests were performed in twelve Flightline Area wells (April, 1988) and an aquifer pumping test was conducted (June, 1990) to determine the hydraulic properties of the Upper Zone aquifer in the Flightline Area at Carswell AFB. The following section presents a discussion of the characteristics of the Upper Zone aquifer as determined from this testing. A more thorough description of the aquifer pumping test procedures and analysis is provided in Appendix F.

Slug Test Results

The ability of the Upper Zone alluvial deposits to transmit ground water was initially characterized based on the results of single-well aquifer tests (slug tests). These tests were performed as described in Section 2.2.5, and analyzed according to the Bouwer and Rice (1976) method.

The calculated hydraulic conductivity values ranged from 22.6 ft/day (7.98×10^{-3} cm/sec) at well LF04-4D to 1.2 ft/day (4.1×10^{-4} cm/sec) at well LF04-4A. The lowest calculated hydraulic conductivities were from wells known to be located outside the main pattern of channel deposits observed in the Flightline Area. The lowest calculated values were from test wells LF04-4A and FT09-12A (Figure 3-12).

The main limitation on slug tests is that they are heavily dependent on a high-quality well intake (screened interval). If well development is inadequate, measured values may be highly inaccurate (decreased conductivities); conversely, if development is very thorough, the measured values may reflect the increased conductivities in the artificially induced gravel pack around the screen. In any case, slug tests usually provide aquifer parameter values that are fairly representative of a small volume of porous media in the immediate vicinity of the well. Aquifer pumping tests, however, usually provide measurements of aquifer parameters that are averaged over a much larger aquifer volume.

Aquifer Pumping Test Results

The data obtained during the June, 1990 Upper Zone aquifer pumping test were analyzed by several methods. Following field plotting of time-drawdown and distance-drawdown measurements, hand plotted observation well drawdown and pumping well recovery data were analyzed by the Cooper-Jacob method. In addition, a computer aquifer analysis program was used. The well hydraulics interpretation program used was WHIP™, which can simulate and analyze both drawdown and recovery tests.

The diagnostic procedures use semilog drawdown (Cooper-Jacob) analyses and Theis recovery analyses to obtain preliminary estimates of the transmissivity and storage coefficient. Theis curves are generated using these values and are graphically compared to the observed data. Portions of the generated curves can be "windowed" so only reliable data are used for the generation of final transmissivity and storage coefficient values. The equations used in the Cooper-Jacob analysis of hand-plotted drawdown and recovery data is provided in Appendix F.

In addition to standard semilog and loglog plots, the effects of various time transformations on the data as well as first and second derivatives of the drawdowns were performed. Observing the derivative drawdown plots was useful for determining that portion of the test data displaying Theis behavior. Additionally, the Dupuit correction for water table conditions was applied to all computer analyses and the initial estimates of transmissivities and storage coefficients were optimized using an ordinary least squares fitting criterion. The Dupuit correction allows for the minimization of the irregularities inherent in field data and applies a more sophisticated mathematical approach to the calculation of transmissivities and storage coefficients.

Three different computer generated plots and analyses were determined to best represent the Upper Zone aquifer hydraulic properties of transmissivity and storage coefficient. These were the observation well (LF04-02) drawdown and recovery analyses and the pumping well (LF04-03) recovery analysis.

Seven additional monitor wells were measured for response to the pumping well during the test. These wells did not respond to pumping. Water level measurements taken in these wells were plotted and are included in Appendix F.

Table 3-4 shows the summarized results of the Flightline Area aquifer pumping test analysis. Both the pumping well (LF04-03) and the observation well (LF04-02) are completed in the generally west to east trend of relatively thick sands and gravels observed in the Flightline Area, and both wells are screened across the entire saturated thickness of the Upper Zone aquifer. The calculated hydraulic conductivity and transmissivity values fall within the range for clean sands and gravels (Freeze and Cherry, 1979) which

TABLE 3-4. SUMMARY OF UPPER ZONE AQUIFER PUMPING TEST RESULTS, FLIGHTLINE AREA, CARSWELL AFB, TEXAS (JUNE, 1990)

Well Number	Type of Test Analyses	Distance From Pumping Well (ft)	Transmissivity	Hydraulic Conductivity	Storage Coefficient (Dimensionless)
LF04-02	Drawdown	50	9771 ft^2/day	835 ft/day (2.9×10^{-1} cm/sec)	1.2×10^{-2}
	Recovery	50	8260 ft^2/day	705 ft/day (2.5×10^{-1} cm/sec)	
LF04-03	Recovery	Pumping Well	9501 ft^2/day	812 ft/day (2.9×10^{-1} cm/sec)	
		Average Values	9177 ft^2/day	784 ft/day (2.8×10^{-1} cm/sec)	1.2×10^{-2}

is consistent with the lithology for the Upper Zone aquifer. The storage coefficient value calculated also falls within the range for clean, unconfined aquifers.

The hydraulic conductivity calculated from the pumping test analysis was significantly higher than that determined from prior slug testing. Based on the limitations of the slug testing discussed earlier, the aquifer pumping test results are more representative of the Upper Zone Aquifer characteristics.

3.4.2 Goodland/Walnut Aquitard

The ground water present in the alluvium is separated from the aquifers below by the low permeability limestones and shales of the Goodland Limestone and Walnut Formation. The aquitard is composed of moist clay and shale layers interbedded with dry limestone beds. Though the Formations are primarily dry, drillers in the area report that small amounts of water enter the borehole while drilling through the Walnut Formation, suggesting that ground water may be moving through the Walnut Formation along bedding planes (Hargis and Associates, 1985). The thickness of the Goodland/Walnut aquitard is approximately 30-40 feet beneath the Flightline Area at Carswell AFB. This thickness is based on two monitor wells drilled through the aquitard and completed in the Paluxy Aquifer during the initial Stage 2 study (Radian, 1989). However, the top of the aquitard is an erosional surface and erosion may have reduced the thickness of the limestone or eroded it entirely in isolated areas, (e.g., at AF Plant 4 beneath Building 189 along Grants Lane, the Goodland Limestone is completely absent and only three feet of the Walnut Formation are present (Hargis and Associates, 1985)).

3.4.3 Paluxy Aquifer

The Paluxy Aquifer, the areal extent of which is shown in Figure 3-13, is the shallowest bedrock aquifer underlying Carswell AFB. In the Carswell AFB area, water in the uppermost part of the Paluxy Formation would

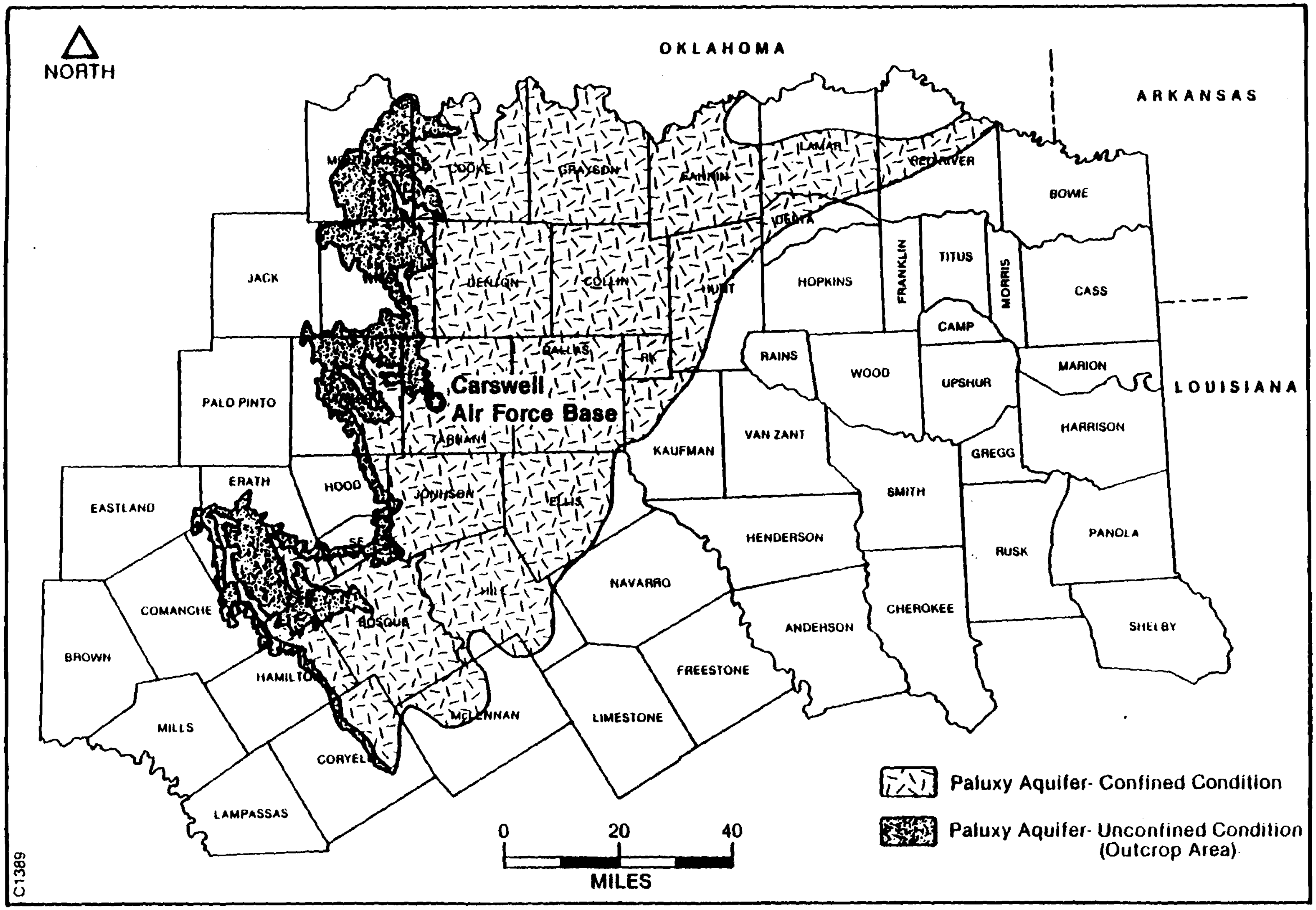

Figure 3-13. Areal Extent of the Paluxy Aquifer, North Texas

naturally occur under confined conditions beneath the Goodland/Walnut aquitard (except where the aquitard has eroded away, as discussed above). However, extensive ground-water pumping in the Fort Worth area, including the City of White Settlement, has lowered the Paluxy Aquifer potentiometric surface below the top of the formation, resulting in unconfined conditions beneath the base. Water-level measurements taken in the Flightline Area Paluxy wells (P-1 and P-2), found the water level to be about five feet below the top of the formation, or about 75 feet below land surface. With the Paluxy Formation having an upper and lower sand member, and the lower member having larger grain size and higher permeability, most water wells are completed in the lower section of the Paluxy Aquifer.

Recharge to the Paluxy Aquifer occurs where the formation crops out west of Carswell AFB in the AF Plant 4 area. The Paluxy Formation also crops out north of the base in the bed of Lake Worth. The lake is a major recharge point for the aquifer and creates a potentiometric high in its vicinity. Regional ground-water flow within the Paluxy Aquifer is southeastward in the direction of the regional dip. At Carswell AFB, ground-water flow is influenced by recharge from Lake Worth, which creates a potentiometric high, and by ground-water withdrawals by the community of White Settlement. This drawdown results locally in a more southerly flow direction within the Paluxy Aquifer.

Transmissivities in the Paluxy Aquifer range from 1,263 to 13,808 gallons per day per foot (gpd/ft), and average 3,700 gpd/ft (CH2M Hill, 1984). The Paluxy Formation thickness ranges from 140 to 190 feet, averaging 160 feet in Tarrant County. The actual water-bearing thickness in the Carswell AFB area probably approximates the formation thickness, but the aquifer is separated into two distinct water-bearing zones, denoted as the upper and middle/lower Paluxy. In some cases, the middle and lower Paluxy are also separated by low-permeability layers. The Paluxy dips uniformly at a rate ranging from 35 to 40 feet per mile and averaging 37 feet per mile. It is encountered at increasing depths eastward, reaching a maximum depth of about 900 feet. During the Phase II Stage 1 Flightline Area investigation (Radian, 1986), short-term aquifer tests (pumping and recovery) were conducted in the

Paluxy Aquifer monitor wells P-1 and P-2. Recovery test data analysis indicates the transmissivity of the upper Paluxy is approximately 1750 gallons per day per foot (235 square feet per day).

3.4.4 Glen Rose Aquitard

Below the Paluxy Aquifer are the fine-grained limestone, shale, marl, and sandstone beds of the Glen Rose Formation. The thickness of the formation in the vicinity of Carswell AFB reportedly ranges from 250 to 450 feet. Although the sands in the Glen Rose Formation yield small amounts of water to wells in Fort Worth and western Tarrant County, the relatively impermeable limestone is an aquitard restricting water movement between the Paluxy Aquifer above and the Twin Mountains aquifer below.

3.4.5 Twin Mountains Aquifer

The Twin Mountains Formation is, geologically, the oldest formation used for water supply in the Carswell AFB area. The formation occurs approximately 600 feet below Carswell AFB. The thickness of the formation ranges from 250 to 430 feet.

Recharge to the Twin Mountains Aquifer occurs west of Carswell AFB, where the formation crops out. Ground-water movement is eastward in the downdip direction. Like the ground water in the Paluxy Aquifer, Twin Mountains ground water occurs under water-table conditions in the recharge area and becomes confined as it moves downdip. Transmissivities in the Twin Mountains Aquifer range from 1,950 to 29,700 gpd/ft and average 8,450 gpd/ft in Tarrant County. Hydraulic conductivities range from 8 to 165 gpd/ft^2 and average 68 gpd/ft^2 in Tarrant County (CH2M Hill, 1984).

4.0 NATURE AND EXTENT OF CONTAMINATION

The Carswell AFB IRP Phase II Stage 1 investigation (1984-85) detected concentrations of TCE and other halogenated hydrocarbons in the Upper Zone ground water in the vicinity of the flightline. In addition, concentrations of several metals exceeded federal drinking water standards in the ground water. During Stage 2 (1987-88), additional work was done to define the extent of the known contaminants present in the Flightline Area.

The primary objective of the addition (Modification 0004) to the original Stage 2 Statement of Work was to further characterize the nature and extent of various contaminants in the Upper Zone ground water beneath the Flightline Area. Specifically, the goal was to define the eastern and western boundaries of the known TCE plume under the Flightline Area, and to collect additional data such that a remedial action could be designed and implemented. In addition, an attempt to determine more conclusively the limits of the known inorganic contamination in the various Flightline Area sites was undertaken.

4.1 Quality Assurance/Quality Control

A primary data set, consisting of analytical results for organic and inorganic compounds in ground and surface water, was collected to characterize ground and surface waters at Carswell AFB and to determine if these waters were contaminated. A quality assurance/quality control (QA/QC) program was incorporated in the data collection effort to control and assess the uncertainty of measurement results.

The uncertainty in the measurement of a chemical concentration in an environmental sample may be broadly divided into components that may be controlled by a laboratory and components that may not be controlled by a laboratory. For example, error due to the analytical method (method error) may be controlled by analyzing the appropriate quality control (QC) samples and using the results as feedback for corrective actions. Error due to the nature of the sample media (matrix effects) may not be controlled, so QC samples are analyzed to assess total uncertainty and provide uncertainty estimates to be used during the interpretation of natural sample results. Therefore, the collection and analysis of quality control samples during the Carswell AFB program served two objectives: (1) to evaluate and control the laboratory component of measurement error; and (2) to evaluate error related to sample variability and matrix effects and ultimately assess total measurement uncertainty.

The approach used to accomplish these objectives is described in Section 4.1.1, along with a general summary and conclusion of the results of the quality control sample analyses. A discussion of the QC results, in regards to the analytical system, is presented in Section 4.1.2. A discussion of the QC results, in regards to total measurement error due to the environmental matrix is presented in Section 4.1.3. A discussion of sample collection documentation, including chain-of-custody, sample hold times, and use of standard forms is presented in Section 4.1.4. Detailed QC results are presented in Appendix H.

4.1.1 QA/QC Approach and Summary

The goals of the QA/QC program were to ensure control over the measurement process in the laboratory and to collect data to assess total measurement error (i.e., non-controllable error due to matrix effects or sample collection). The quality of the measurement program was also enhanced through the use of standard analytical methods, standardized data collection forms, chain-of-custody procedures, and standard sample hold times. The reference analytical methods used on this project are identified in Table 4-1. Quality control requirements described in the reference methods and the approved Carswell AFB Quality Assurance Project Plan (QAPP) were followed for all analyses.

QC samples used to control and/or assess measurement error included blanks, spikes, and replicates. A glossary of QC sample types is presented in Table 4-2. Analysis of these QC samples provided information related to contamination (false-positives), bias, and variability, respectively. The

TABLE 4-1. STANDARD METHODS USED FOR CHEMICAL ANALYSES

IRP Test Name	Radian Code	IRP Code
Purgeable Halocarbons	601EW001	E601
Arsenic	ASGSWA00	SW7060
Chloride (Titrimetric, Mercuric Nitrate)	CLTEWN00	E325.3
Fluoride, Potentiometric, ION Selective Electrode	F_SEWA00	E340.2
Total Recoverable Petroleum Hydrocarbons	HCTEWN00	E418.1
Mercury (cold vapor, manual)	HGC_WN00	E245.1
Inductively Coupled PLASMA (ICP) Metals Screen	ICPSWN00	SW6010
Nitrate ION	NO3EWA00	E353.2
Orthophosphate	OPOEWN00	E365.2
Lead (Furnace)	PBGSWA00	SW7421
Selenium	SEGSWA00	SW7740
Sulfate by Nephelometry	SFN_WN00	SW9038
Filterable Residue (Also known as Total Dissolved Solids)	TDSEWN00	E160.1
Nitrate ION	NO3EWN00	E353.2
Purgeable Aromatics	602EW001	E602

TABLE 4-2. GLOSSARY OF QC SAMPLE TYPES

Blanks	
Equipment Rinse	A water rinse of sampling equipment between sample locations to quantitate cross-contamination.
Trip	Reagent grade water sealed in VOA vials in the laboratory, transported to the field and back to the laboratory with natural samples to quantitate shipment and laboratory storage contamination.
Ambient Condition	Reagent grade water poured into sample vials in the field and allowed to sit open to the ambient air for a specified period to quantitate air-borne contamination.
<u>Replicates</u>	
Field Duplicates	Samples split in the field into two containers and submitted blind for analysis, to quantitate natural variability of constituents in a specific matrix.
<u>Spikes</u>	
Matrix/spike/matrix spike duplicates (MS/MSDs)	Known quantities of target analytes are introduced into a split of the sample before preparation. A MS/MSD pair is performed at a minimum frequency of 5% or one per batch of less than 20 samples. Used to quantitate bias and imprecision in analytical results due to the natural matrix.
Surrogate	Known quantity of a compound that is not expected to occur naturally in the sample. All samples to be analyzed for organic constituents are spiked with surrogate compounds. Used to quantitate bias in analytical results for classes of compounds.

approach to using these QC samples to control laboratory performance and assess total measurement error is described in the following sections.

Approach and Summary of Laboratory Matrix QC Efforts

The QA effort to control and assess analytical error consisted of QC samples, analyzed along with natural samples, and a prescribed set of corrective actions to implement when error exceeded data quality objectives. Thus, a feedback mechanism was used which enabled the lab to continuously monitor bias and imprecision in a laboratory matrix. Types of QC samples with acceptance criteria and limits, as well as the prescribed corrective actions, were presented in Table 1.10-1 of the approved QAPP. The QC samples used to control precision and accuracy in the laboratory matrix included continuing calibration control samples, laboratory quality control check (QCCS) samples, and for metals by SW6010 (ICAP), ICP interference check samples. Data quality objectives for laboratory-controllable parameters during this program were presented in Table 1.4-1 in the approved QAPP, in terms of precision and accuracy, and are reproduced in this document as Table 4-3.

In summary, the analytical system was in control for all analyses. Quality control check samples (QCCS) or continuing calibration check samples were always used as a final analysis if there was a concern about system control.

Laboratory blanks indicate a potential for false-positive results due to laboratory contamination. Maximum concentrations found in lab. blanks are presented below with specific analytes:

TABLE 4-3. PRECISION AND ACCURACY OBJECTIVES FOR THE LABORATORY MATRIX

Parameter	Method	Precision[a]	Accuracy[b]
Total Petroleum Hydrocarbons	EPA 418.1-IR	Not specified	Not specified
Metals Screen (23 metals)	SW846 6010-ICP (modified)	20%	±15%
Arsenic	SW846 7060 Furnace AA	20%	±15%
Lead	SW846 7421 Furnace AA	20%	±15%
Mercury	SW846 7471 Cold Vapor AA	20%	±20%
Selenium	SW846 7740 Furnace AA	20%	±15%
Volatile Halocarbons	EPA 601	50%	±30% to 110%[c]
Volatile Aromatics	EPA 602	50%	±4% to 65%[c]
Chloride	EPA 325.3	15%	±15%
Sulfate	SW846 9038	15%	±10%
Fluoride	EPA 340.2	10%	±10%
Total Dissolved Solids	EPA 160.1	20%	±15%

[a] Coefficient of variation (relative standard deviation) for replicate determinations (exclusive of sampling variability).

[b] Total error for a single measurement, including both systematic error (bias) and random error (variability due to imprecision), expressed as a percentage of the measured value.

[c] Range of relative error for species of interest, based on EPA method validation testing. See method for further explanation.

• EPA 601	-	Tetrachloroethene	0.17 μg/L;
		Trichloroethene	1.3 μg/L;
• EPA 325.3	-	Chloride	1.5 mg/L;
• SW6010	-	Aluminum	0.53 mg/L;
		Beryllium	0.0023 mg/L;
		Copper	0.053 mg/L;
		Nickel	0.021 mg/L;
		Silver	0.051 mg/L;
		Strontium	0.0047 mg/L;
		Vanadium	0.025 mg/L;
		Zinc	0.044 mg/L;
• EPA 365.2		Orthophosphate	0.012 mg/L; and,
• SW7421		Lead	0.0099 mg/L.

A more detailed discussion of laboratory matrix QC samples is provided in Section 4.1.2.

Approach and Summary of Environmental Matrix QC Efforts

Total measurement error includes components of error associated with matrix effects (recovery), lack of homogeneity in the matrix (variability), and sample collection (variability and contamination). Total error may be expressed in terms of bias, measured by matrix and surrogate spike results; imprecision, measured by matrix spike duplicate and field duplicate results; and contamination, measured by field blanks such as ambient condition and equipment rinse blanks. Imprecision may be expressed in terms of the pooled coefficient of variation (CV) for matrix spike duplicate and field duplicate results. Matrix spike duplicate results allow for estimates of imprecision at an established concentration level above the detection limit, whereas concentrations of target analytes in field duplicate samples may vary widely or even be not detectable.

In summary, field blanks indicated a potential for false-positive results due to field contamination. Generally, field blanks contained very low concentrations for common organic and inorganic compounds. Natural sample results near laboratory and field blank concentrations may considered false-positive results. Estimates of imprecision and bias are presented in Section 4.1.3.

Approach and Summary of Sample Collection QC Efforts

The QA effort to control and/or evaluate sample collection error consisted of using standard sample collection methods, standard sample holding times until analysis, standard forms to document sample collection and chain-of-custody, along with trip blanks to quantitate bias (i.e., contamination) due to sample handling, shipment or storage. The standard forms used at Carswell AFB originated with the Air Force IRP program and may be found in the data collection handbook. Chain-of-custody forms are presented as Figure 1.6-2 in Section 1.6.1 of the QAPP.

A feed-back mechanism to control sample collection error was not possible for the Carswell project because field teams finished sample collection before sample analysis was complete. While there were some inconsistencies in hold times for trip blanks and signatures on chains-of-custody, no sample results were invalidated. A discussion of the completeness of sample collection QC efforts is presented in Section 4.1.4.

4.1.2 Laboratory Matrix QC Sample Results

Bias and imprecision in results is most controllable for the analytical system because QC samples may be analyzed along with natural matrix samples and a batch reanalyzed if QC samples indicate the system is out of control. As discussed in Section 4.1.1, and the QAPP, data quality objectives, Table 4-3, are for QC samples using reagent water as the matrix. Results for samples in natural matrices would not be expected to be as unbiased nor precise. If imprecision or bias exceed these data quality objectives, then the analytical system is out of control and must be corrected, and affected samples reanalyzed. Bias due to laboratory contamination is not included in Table 4-3. Generally, any systematic contamination for laboratory sources is not allowed. However, the presence of some common lab contaminants is allowed and corrective action is taken only when concentrations reach a significant level as directed in the QAPP.

Instrument calibrations were performed according to laboratory standard operating procedures (SOPs) which reference the standard methods specified in the QAPP. One problem occurred with the calibration curve for a gas chromatograph (GC) used for 601 analyses. This problem was documented in the ITIR and the solution and a discussion are represented here.

As pointed out in the ITIR, this problem does not invalidate any sample results for samples analyzed by Method 601 and does not make this project incomplete. The calibration curve for Method 601 analyses on instrument "B" was not within specifications. The fifth, and highest, calibration point (30 ppb) was inaccurate and thus caused results to be biased high. To solve this problem, data generated on instrument "B" for 601 analyses was recalculated using a four point calibration curve, dropping the 30 ppb calibration point, with the new highest point of 15 ppb. New reports were issued and affected results flagged. Second column confirmation need be only qualitative for Carswell AFB analyses, so these results (i.e., Instrument B data) will be used solely for second column confirmation. Results for instrument "5" were considered the "primary" result and site evaluations will be based on this quantitation.

QC sample results for organic methods are used internally by the laboratory to determine if the analytical system remains in control. These results are not reported. Since these results are used as a feedback mechanism on system control and not to evaluate total bias or imprecision after reporting, it is the laboratory's responsibility to maintain system control. For this discussion it is assumed all samples were analyzed by Method 601 and Method 602 when the system was in control.

4.1.2.1 Laboratory Matrix Blanks

A list of analytes detected in laboratory matrix blanks is presented in Table 4-4 with a count of the number of times detected and maximum concentrations. Generally, there is little concern for false-positive results due to laboratory contamination. However, for the analytes listed in Table 4-4, it is possible for sporadic false-positive results. Corrective actions outlined in the QAPP were followed regarding laboratory contamination. Therefore, no sample results were invalidated due to laboratory contamination. Summary and detailed results for all blanks are presented in Table 1 and Table 2 of Appendix H, respectively.

4.1.2.2 Laboratory Matrix Spikes

Continuing calibration and quality control check samples (QCCS) check samples were used to determine if the analytical system was in control for methods by AA, ICAP, or cold-vapor graphite furnace AA; fluoride, chloride, total hydrocarbons, orthophosphate, and total dissolved solids. Results of these samples are presented in Table 4-5. Detailed results are presented in Table 3 of Appendix H. A comparison of Table 4-5 to data quality objectives (DQOs) from Table 4-3, indicates the analytical system was in control for these analyses. Interference check samples were also analyzed for metals analyzed by Method SW6010, metals by ICAP. Acceptance criteria for interference check samples are recovery ± 20% of true concentration. Results indicate generally there was little interference and error was less than data quality objectives. Iron results indicated greater interference error than expected. The calculated mean recovery and coefficient of variation (CV) for iron was mean = 77% and CV = 24.6%, respectively.

Blank spike QC samples (i.e., method spikes) were also used to monitor the analytical system for bias and imprecision. Blank spikes are reagent grade water, spiked with known concentrations of a specified analyte and the sample taken through the preparation described for the appropriate method. Blank spike analyses were performed for metals by AA and ICAP,

TABLE 4-4. SUMMARY OF LAB BLANK RESULTS, CARSWELL AFB, TEXAS

Method	Type	Parameter	Total Number of Blanks	Total Number Above Detection Limit	Concentration Range Minimum Units	Concentration Range Maximum Units	Maximum Detection Limit
Halocarbons by EPA 601	Reagent Blank	Tetrachloroethene	39	1	0.170	0.17	0.100 μg/L
		Trichloroethene	39	1	1.300	1.3	0.200 μg/L
Chloride, by titration	Method Blank	Chloride	16	8	1.400	1.5	1.000 mg/L
	Preparation	Chloride	5	2	1.440	1.5	1.000 mg/L
ICP 25 Element Scan	Calibration	Beryllium	38	1	0.0023	0.0023	0.0020 mg/L
		Nickel	38	1	0.021	0.021	0.020 mg/L
		Silver	38	3	0.011	0.051	0.010 mg/L
		Strontium	38	2	0.0041	0.0047	0.0030 mg/L
	Method Blank	Aluminum	17	1	0.530	0.53	0.200 mg/L
		Copper	17	2	0.023	0.053	0.020 mg/L
		Zinc	17	6	0.025	0.044	0.020 mg/L
	Preparation	Aluminum	6	1	0.530	0.53	0.200 mg/L
		Silver	6	1	0.014	0.014	0.010 mg/L
		Vanadium	6	1	0.025	0.025	0.020 mg/L
Orthophosphate	Method Blank	Orthophosphate	13	1	0.012	0.012	0.010 mg/L
Lead by SW7421	Initial Calibration Blank	Lead	11	4	0.0030	0.0092	0.0030 mg/L
	Method Blank	Lead	17	4	0.0040	0.0042	0.0030 mg/L
	Preparation	Lead	9	5	0.0040	0.0099	0.0030 mg/L

TABLE 4-5. SUMMARY OF QUALITY CONTROL CHECK SAMPLE (QCCS) RESULTS, CARSWELL AFB, TEXAS

Parameter	Number of Samples	Mean % Recovery	Precision CV (%)	Accuracy Mean Relative Error (±%)
ARSENIC BY SW7060				
Continuing Calibration Control Sample				
Arsenic	53	95.9	4.5	5.0
Laboratory Control Sample (QCCS)				
Arsenic	2	90.3	5.8	9.7
CHLORIDE, BY TITRATION				
Continuing Calibration Control Sample				
Chloride	15	97.5	1.2	2.5
FLUORIDE BY EPA 340.2]				
Continuing Calibration Control Sample				
Fluoride	17	96.4	3.6	4.2
HYDROCARBONS, TOTAL E418.1				
Continuing Calibration Control Sample				
Hydrocarbons	4	93.6	3.8	6.4
MERCURY BY COLD VAPOR				
Continuing Calibration Control Sample				
Mercury	50	96.7	13.6	5.4
ICP 25 ELEMENT SCAN				
Continuing Calibration Control Sample				
Aluminum	41	101.3	2.6	2.3
Antimony	38	101.3	2.9	2.3
Arsenic	40	103.1	2.8	3.6
Barium	39	99.8	3.2	2.6
Beryllium	43	100.9	4.1	3.8
Boron	38	99.8	3.9	3.2
Cadmium	40	103.7	4.3	5.4
Calcium	38	104.3	2.2	4.3
Chromium	41	100.8	2.7	2.2
Cobalt	36	102.2	2.8	3.1
Copper	40	102.7	3.8	4.1
Iron	40	98.8	2.1	1.9
Lead	39	104.0	4.0	5.1
Magnesium	39	100.5	2.5	2.0
Manganese	41	103.6	3.1	4.3
Molybdenum	35	99.0	3.2	2.9
Nickel	39	102.9	2.9	3.5
Potassium	42	100.7	2.5	2.2
Seleniuum	41	103.1	2.3	3.3
Silicon	42	101.5	3.5	3.1
Silver	36	101.4	4.3	3.9
Sodium	40	101.8	12.3	4.0
Strontium	44	100.2	2.7	2.3
Thallium	41	100.4	2.9	2.4
Vanadium	41	102.5	3.1	3.7
Zinc	38	103.9	2.4	4.0
ICP Interference Check Sample				
Aluminum	17	92.7	6.0	7.7
Barium	26	103.8	2.3	3.8
Beryllium	27	104.4	2.4	4.5
Cadmium	28	102.9	2.2	3.1
Calcium	17	82.6	15.7	17.6
Chromium	28	104.6	2.7	5.0
Cobalt	28	107.3	3.4	7.7
Copper	28	105.0	4.1	5.9
Iron	17	77.0	24.6	24.3
Lead	30	104.5	4.6	5.6
Magnesium	17	88.1	10.0	12.2
Manganese	27	102.7	4.9	4.7

(Continued)

TABLE 4-5 (Continued)

Parameter	Number of Samples	Mean % Recovery	Precision CV (%)	Accuracy Mean Relative Error (±%)
Nickel	28	102.2	3.9	3.8
Silver	30	101.7	4.4	4.1
Vanadium	30	99.6	6.2	4.3
Zinc	28	106.2	3.4	6.7
Initial Calibration Control Sample				
Aluminum	2	100.4	1.3	.9
Barium	2	101.0	.3	1.0
Beryllium	2	101.3	.3	1.3
Cadmium	2	97.2	.8	2.8
Calcium	2	101.8	.1	1.8
Chromium	2	100.6	.2	.6
Cobalt	2	99.2	.6	.8
Copper	2	92.9	.2	7.1
Iron	1	104.3		4.3
Lead	2	101.2	2.6	1.9
Magnesium	1	101.5		1.5
Manganese	2	85.5	.5	14.5
Nickel	2	100.1	2.4	1.7
Silver	2	92.2	.2	7.8
Vanadium	2	90.9	.2	9.1
Zinc	2	97.7	.2	2.3
Laboratory Control Sample (QCCS)				
Aluminum	2	96.9	.5	3.1
Antimony	2	94.5	3.7	5.5
Arsenic	2	117.0	.0	17.0
Barium	2	99.0	.0	1.0
Beryllium	2	100.3	1.0	.7
Boron	2	99.0	1.4	1.0
Cadmium	2	97.4	.9	2.6
Calcium	2	100.0	1.4	1.0
Chromium	2	98.3	.4	1.8
Cobalt	2	97.9	.1	2.1
Copper	2	97.8	.4	2.3
Iron	2	96.3	1.9	3.7
Lead	2	98.8	1.1	1.2
Magnesium	2	96.6	1.6	3.4
Manganese	2	97.4	.6	2.6
Molybdenum	2	97.4	.7	2.6
Nickel	2	98.4	.9	1.7
Potassium	2	95.5	3.1	4.5
Selenium	2	101.5	.7	1.5
Silicon	2	92.9	5.3	7.1
Silver	2	92.0	4.7	8.0
Sodium	2	94.6	.6	5.4
Strontium	2	98.9	.2	1.2
Thallium	2	96.8	1.8	3.3
Vanadium	2	95.9	.2	4.1
Zinc	2	99.1	1.3	.9
NITRATE BY E353.2				
Continuing Calibration Control Sample				
Nitrate	20	99.7	4.4	3.6
ORTHOPHOSPHATE				
Continuing Calibration Control Sample				
Orthophosphate	22	99.0	3.3	2.5
LEAD BY SW7421				
Continuing Calibration Control Sample				
Lead	56	103.2	4.3	4.6
Laboratory Control Sample (QCCS)				
Lead	2	108.3	2.2	8.3

(Continued)

TABLE 4-5 (Continued)

Parameter	Number of Samples	Mean % Recovery	Precision CV (%)	Accuracy Mean Relative Error (±%)
SELENIUM BY SW7740				
Continuing Calibration Control Sample				
Selenium	46	97.6	5.6	5.1
Laboratory Control Sample (QCCS)				
Selenium	1	90.0		10.0
SULFATE				
Continuing Calibration Control Sample				
Sulfate	13	98.6	2.4	2.2
TOTAL DISSOLVED SOLIDS				
Laboratory Control Sample (QCCS)				
Total Dissolved Solids	6	100.6	3.5	2.5

chloride, fluoride, hydrocarbons, nitrate and orthophosphate. A summary of results for these QC samples is presented in Table 4-6. Surrogate spikes were also added to blank spike samples. Surrogate recoveries are presented in Table 4-7. Detailed results are presented in the laboratory QC matrix section of Table 4 of Appendix H. Results for all blank spikes except antimony were within the QAPP specified acceptance criteria for recovery. Ten of the 14 antimony sample results were slightly below 75% recovery.

Laboratory QC samples (blanks, method spikes, etc.) for EPA 601 and EPA 602 analyses were spiked with the surrogate compound 1-bromo-4-fluorobenzene. For Method 601, halocarbons by GC, surrogate spike recoveries for laboratory QC samples indicate a bias towards high recovery with little imprecision. Six of 79 recoveries were greater than acceptance criteria limits of 140%. For Method 602, aromatics by GC, surrogate spike recoveries for laboratory QC samples indicate little bias or imprecision. All recoveries were within acceptance criteria of 40% to 140%.

Laboratory Matrix Replicates

Analytical duplicates (i.e., duplicate analysis of the same prepared sample at the instrument) were used to determine if the imprecision associated with the analytical system was in control relative to precision objectives. Results of analytical duplicates indicated slightly greater variability, as estimated by coefficient of variation (CV), than expected for the following analytes:

- Nickel (SW6010) - 24%;
- Lead (SW7421) - 47%;
- Selenium (SW7740) - 51%;
- Orthophosphate (E365.2) - 28%.

Results of analytical duplicates are summarized in Table 5 of Appendix H.

TABLE 4-6. SUMMARY OF SPIKE RESULTS, CARSWELL AFB, TEXAS

SUMMARY OF SPIKE RESULTS FOR MATRIX = Laboratory Water

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
Arsenic by SW7060						
Method (Blank) Spike						
Arsenic	18	83.0	4.57908	12	0	85.0 - 115.0
Chloride, by titration						
Method (Blank) Spike						
Chloride	1	106.0		0	1	
Hydrocarbons, total E418.1						
Method (Blank) Spike						
Hydrocarbons	1	104.0		0	0	80.0 - 120.0
ICP 25 element scan						
Method (Blank) Spike						
Aluminum	14	95.5	3.52355	1	0	90.0 - 110.0
Antimony	14	73.0	3.18113	14	0	90.0 - 110.0
Arsenic	14	85.1	5.12106	12	0	90.0 - 110.0
Barium	14	98.7	2.76891	0	0	90.0 - 110.0
Beryllium	14	100.7	2.79432	0	0	90.0 - 110.0
Boron	14	45.8	13.65921	14	0	90.0 - 110.0
Cadmium	14	96.6	2.62954	0	0	90.0 - 110.0
Calcium	14	92.5	9.49572	4	1	90.0 - 110.0
Chromium	14	97.6	2.49302	0	0	90.0 - 110.0
Cobalt	14	97.4	2.45916	0	0	90.0 - 110.0
Copper	14	96.5	2.70276	0	0	90.0 - 110.0
Iron	14	95.9	3.42736	1	0	90.0 - 110.0
Lead	14	93.8	3.64649	1	0	90.0 - 110.0
Magnesium	14	87.2	3.72134	13	0	90.0 - 110.0
Manganese	14	97.1	2.35759	0	0	90.0 - 110.0
Molybdenum	14	92.8	2.64073	3	0	90.0 - 110.0
Nickel	14	97.3	2.68349	0	0	90.0 - 110.0
Potassium	14	34.8	4.05501	14	0	90.0 - 110.0
Selenium	14	70.7	2.88177	14	0	90.0 - 110.0
Silicon	14	79.2	8.03564	13	0	90.0 - 110.0
Silver	14	94.0	5.35741	2	0	90.0 - 110.0
Sodium	14	85.7	4.35145	13	0	90.0 - 110.0
Strontium	14	99.2	2.67113	0	0	90.0 - 110.0
Thallium	14	89.3	4.70496	9	0	90.0 - 110.0
Vanadium	14	94.9	3.11534	0	0	90.0 - 110.0
Zinc	14	96.2	5.45483	1	0	90.0 - 110.0
Orthophosphate						
Method (Blank) Spike						
Orthophosphate	5	78.0	40.80044	0	5	

(Continued)

73 110

TABLE 4-6. (CONTINUED)

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
Lead by SW7421						
Method (Blank) Spike						
Lead	17	94.5	6.15363	1	0	85.0 - 115.0
Selenium by SW7740						
Method (Blank) Spike						
Selenium	9	89.3	8.25321	3	0	85.0 - 115.0

TABLE 4-7. SUMMARY OF SURROGATE SPIKE RESULTS, CARSWELL AFB, TEXAS

SUMMARY OF SPIKE RESULTS FOR MATRIX = Laboratory Water

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
Halocarbons by EPA 601						
Matrix Spike						
1-Bromo-4-fluorobenzene	12	130.7	9.71721	0	2	40.0 - 140.0
Surrogate Spike						
1-Bromo-4-fluorobenzene	67	124.8	10.32149	0	4	40.0 - 140.0
Aromatics by EPA 602						
Matrix Spike						
1-Bromo-4-fluorobenzene	4	99.5	5.97216	0	0	40.0 - 140.0
Surrogate Spike						
1-Bromo-4-fluorobenzene	28	96.5	16.07271	0	0	40.0 - 140.0

4.1.3 Environmental Matrix QC Sample Results

Measurement bias and imprecision are confounded with environmental variability in natural matrix samples. Since environmental variability (eg. non-uniform distribution of pollution, variation in natural background concentrations over space and time, etc) will not be adequately characterized, measurement error and bias may be quantified but not controlled. Also, generally sample analyses are performed after field teams have finished at the site, so timely re-sampling is not an option. Therefore, the following results are used to qualify interpretations, not to validate procedures or sample results. Acceptance criteria as specified in Table 1.10-1 of the QAPP are used throughout this discussion as an indication that bias and imprecision are normal or abnormal based on historical analyses. Generally, the QAPP specified corrective action for results outside acceptance criteria is to flag data and assume matrix interference. Five types of QC samples were used on the Carswell project to quantify measurement bias and imprecision that is confounded with environmental variability. These five QC sample types are:

- Matrix spikes (quantify bias);
- Surrogate spikes (quantify bias);
- Matrix spike duplicates (quantify imprecision);
- Predigestion duplicates (quantify imprecision due to matrix, preparation and analytical effects); and
- Field duplicates (quantify imprecision due to sampling, matrix, preparation and analytical effects).

False-positive results due to wind-blown contamination or cross-contamination from using non-dedicated sampling equipment are possible during any sampling effort. Field blanks are used to identify and estimate the quantity of contamination that may be associated with sampling efforts.

Ambient condition and equipment blanks were used during the Carswell ground-water program.

Contamination, bias and imprecision are discussed in following sections by QC sample type. Results that exceeded expectations base on historical laboratory bias and imprecision estimates are discussed for appropriate methods.

Field Blanks

A synopsis of the results for compounds detected in field blanks and the maximum concentration detected are presented in Table 4-8. All results for field blanks are summarized and presented in detail in Table 1 and Table 2 of Appendix H, respectively.

Spikes

Analytical, matrix and surrogate spikes were used to evaluate bias on the Carswell project. Analytical spikes are added after preparation, immediately before analysis, so only bias and imprecision due to the matrix, or analyst's error, is quantified. Matrix spikes are added to the sample before preparation and provide information about total matrix effects. Bias and imprecision estimates from matrix spikes include method preparation error. Analytical spike results should complement results of matrix spike studies regarding error due to the natural matrix. Surrogate spikes are known concentrations of compounds not expected to be found naturally in samples, added to samples. Surrogate recoveries indicate potential bias in recovery for classes of compounds. The corrective action for results outside acceptance criteria for all types of spike results is to recheck calculations and if an error is not found, assume a matrix effect.

Detailed spike results are presented in Table 4 (detailed results) of Appendix H. Results of these QC samples are discussed below for both ground-water and surface water matrices.

TABLE 4-8. SUMMARY OF FIELD BLANK RESULTS, CARSWELL AFB, TEXAS

Method	Type	Parameter	Total Number of Blanks	Total Number Above Detection Limit	Concentration Range Minimum Units - Maximum Units	Maximum Detection Limit
Halocarbons by EPA 601	Ambient Conditions Blank	1,2-Dichloroethane	4	4	0.790 - 1.2	0.100 µg/L
		Methylene chloride	4	2	0.540 - 0.67	0.400 µg/L
		Tetrachloroethene	4	1	0.160 - 0.16	0.100 µg/L
		Trichloroethene	4	4	0.500 - 1.0	0.200 µg/L
		Trichlorofluoromethane	4	3	0.260 - 0.42	0.200 µg/L
		Vinyl chloride	4	3	0.290 - 1.6	0.200 µg/L
	Equipment Blank	Methylene chloride	4	2	0.490 - 0.64	0.400 µg/L
		Trichloroethene	4	4	0.410 - 0.58	0.200 µg/L
		Trichlorofluoromethane	4	1	0.330 - 0.33	0.200 µg/L
		Vinyl chloride	3	1	0.710 - 0.71	0.200 µg/L
	Trip Blank	Methylene chloride	12	2	2.000 - 6.7	4.000 µg/L
		Trichloroethene	12	1	0.260 - 0.26	2.000 µg/L
		Vinyl chloride	12	1	0.610 - 0.61	2.000 µg/L
Aromatics by EPA 602	Trip Blank	Chlorobenzene	4	1	0.280 - 0.28	0.200 µg/L
		Toluene	4	1	0.490 - 0.49	0.200 µg/L
		Xylenes (total)	4	1	0.630 - 0.63	0.200 µg/L
ICP 25 element scan	Equipment Blank	Barium	14	7	0.025 - 0.12	0.011 µg/L
		Beryllium	14	1	0.0030 - 0.0030	0.0022 µg/L
		Calcium	14	1	1.000 - 1.0	1.100 µg/L
		Iron	14	2	0.046 - 0.047	0.044 µg/L
		Lead	14	2	0.055 - 0.057	0.055 µg/L
		Silicon	14	1	1.200 - 1.2	1.100 µg/L
		Silver	14	1	0.010 - 0.010	0.011 µg/L
		Sodium	14	3	1.100 - 1.8	1.100 µg/L
		Strontium	14	7	0.0039 - 0.0068	0.0033 µg/L
		Zinc	14	6	0.022 - 0.065	0.022 µg/L
Nitrate by E353.2	Equipment Blank	Nitrate	7	3	0.020 - 0.50	0.020 mg/L
Lead by SW7421	Equipment Blank	Lead	14	8	0.0034 - 0.013	0.0060 mg/L
Sulfate	Equipment Blank	Sulfate	7	1	1.400 - 1.4	1.000 mg/L
Total dissolved solids	Equipment Blank	Total dissolved solids	7	1	2600.0 - 2600.0	9.000 mg/L

4.1.3.1 Ground-Water Matrix

Generally, spike recoveries were within expected limits. Matrix spike and surrogate spike recoveries are presented in Table 4-9 and Table 4-10, respectively. Exceptions are discussed below by spike type and method.

Arsenic by SW846 Method 7060 -- Matrix spike recoveries for arsenic indicate little overall bias but imprecision. Three recoveries were below acceptance criteria limits and one recovery above criteria limits. Mean recovery (standard deviation) for 20 matrix spiked samples was 91% (32%). Analytical spike recoveries for arsenic were also biased. Seven out of 144 analytical spike recoveries were less than the 75% acceptance criteria.

Lead by SW846 Method 7421 -- Matrix spike recoveries for lead by SW7421 indicate little bias but fair imprecision. Two sample recoveries out of 20 samples were below the lower acceptance criteria limit of 75% and six recoveries out of 20 were above upper limits of 125%. Mean (standard deviation) recovery was 107% (32%). Analytical spike recoveries also indicated bias and imprecision. Twenty-six of 144 analytical spikes were greater than the analytical spike acceptance criteria of 125%. QCCS and/or continuing calibration check samples were analyzed after the out-of-control spikes to prove the system was in control. Recoveries were within limits for these QC samples, so the laboratory assumed matrix effects influenced recovery and no samples were reanalyzed.

Selenium by SW846 Method 7740 -- Analytical spikes for selenium indicated bias and imprecision. Thirty-four of 144 analytical spikes had recoveries less than the lower acceptance criteria of 75%. Analysis of QCCS and/or continuing calibration check samples indicated the system was in control and so matrix effects were assumed to cause recoveries less than the minimum acceptance limit.

TABLE 4-9. SUMMARY OF SPIKE RESULTS, CARSWELL AFB, TEXAS

SUMMARY OF SPIKE RESULTS FOR MATRIX - Groundwater

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
Halocarbons by EPA 601						
Matrix Spike						
1,1-Dichloroethene	4	64.8	29.76995	0	0	28.0 - 167.0
Chlorobenzene	4	106.3	13.50000	0	0	38.0 - 150.0
Trichloroethene	4	83.8	7.41058	0	0	35.0 - 146.0
Aromatics						
Matrix Spike						
Benzene	4	97.0	9.38083	0	0	39.0 - 150.0
Chlorobenzene	4	105.3	11.23610	0	0	55.0 - 135.0
Toluene	4	105.0	21.36976	0	0	46.0 - 148.0
Arsenic by SW7060						
Analytical Spike Arsenic	144	93.6	12.16579	7	0	75.0 - 125.0
Matrix Spike Arsenic	20	91.3	32.06059	3	1	75.0 - 125.0
Chloride, by titration						
Matrix Spike Chloride	14	102.3	6.16522	0	0	80.0 - 120.0
Fluroide by EPA 340.2						
Matrix Spike Fluoride	22	101.6	3.74439	0	0	85.0 - 115.0
Hydrocarbons, total E418.1						
Matrix Spike Hydrocarbons	4	88.8	5.05800	0	0	80.0 - 120.0
Mercury by cold vapor						
Analytical Spike Mercury	144	94.0	10.82663	2	0	75.0 - 125.0

(Continued)

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TABLE 4-9. (Continued)

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
Matrix Spike						
Mercury	20	98.1	6.32018	0	0	75.0 - 125.0
ICP 25 element scan						
Analytical Spike						
Aluminum	144	91.4	5.38505	1	0	75.0 - 125.0
Antimony	144	85.9	5.35358	0	0	75.0 - 125.0
Arsenic	144	102.2	4.63232	0	0	75.0 - 125.0
Barium	144	88.8	8.00610	1	0	75.0 - 125.0
Beryllium	144	89.8	4.22653	0	0	75.0 - 125.0
Boron	144	104.6	13.25564	0	0	75.0 - 125.0
Cadmium	144	86.7	3.74249	0	0	75.0 - 125.0
Calcium	144	93.2	5.83919	0	0	75.0 - 125.0
Chromium	144	86.6	3.96527	0	0	75.0 - 125.0
Cobalt	144	85.9	3.78757	0	0	75.0 - 125.0
Copper	144	88.6	4.14678	0	0	75.0 - 125.0
Iron	144	86.5	3.65457	0	0	75.0 - 125.0
Lead	144	83.6	4.66458	0	0	75.0 - 125.0
Magnesium	144	90.1	3.46163	0	0	75.0 - 125.0
Manganese	144	85.1	4.38962	0	0	75.0 - 125.0
Molybdenum	144	86.5	3.90081	0	0	75.0 - 125.0
Nickel	144	85.9	3.95909	0	0	75.0 - 125.0
Potassium	144	90.4	4.20580	0	0	75.0 - 125.0
Selenium	144	90.5	5.96257	0	0	75.0 - 125.0

(Continued)

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TABLE 4-9. (Continued)

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
Silicon	144	94.7	9.04646	0	0	75.0 - 125.0
Silver	144	86.5	4.62265	0	0	75.0 - 125.0
Sodium	144	92.4	4.30209	0	0	75.0 - 125.0
Strontium	144	88.9	4.40489	0	0	75.0 - 125.0
Thallium	144	85.0	5.38642	0	0	75.0 - 125.0
Vanadium	144	87.5	3.46611	0	0	75.0 - 125.0
Zinc	144	87.4	3.96414	0	0	75.0 - 125.0
Matrix Spike						
Aluminum	20	114.3	46.19079	0	3	75.0 - 125.0
Antimony	20	86.3	5.31235	0	0	75.0 - 125.0
Arsenic	20	107.1	9.02569	0	1	75.0 - 125.0
Barium	20	92.7	5.23425	0	0	75.0 - 125.0
Beryllium	20	93.5	5.92475	0	0	75.0 - 125.0
Boron	20	107.7	15.05114	0	2	75.0 - 125.0
Cadmium	20	90.3	4.74480	0	0	75.0 - 125.0
Calcium	20	77.4	48.30634	7	2	75.0 - 125.0
Chromium	20	90.7	5.15318	0	0	75.0 - 125.0
Cobalt	20	89.8	5.43478	0	0	75.0 - 125.0
Copper	20	92.1	5.56209	0	0	75.0 - 125.0
Iron	20	93.3	13.79121	1	1	75.0 - 125.0
Lead	20	89.0	6.47261	0	0	75.0 - 125.0
Magnesium	20	92.9	7.86665	0	0	75.0 - 125.0

(Continued)

TABLE 4-9. (Continued)

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
Manganese	20	90.1	5.67984	0	0	75.0 - 125.0
Molybdenum	20	90.7	4.73814	0	0	75.0 - 125.0
Nickel	20	90.3	5.86582	0	0	75.0 - 125.0
Potassium	20	106.2	29.28732	0	2	75.0 - 125.0
Selenium	20	92.4	6.36003	0	0	75.0 - 125.0
Silicon	20	177.4	170.12419	0	8	75.0 - 125.0
Silver	20	90.6	4.78374	0	0	75.0 - 125.0
Sodium	20	90.5	19.02761	4	1	75.0 - 125.0
Strontium	20	91.4	5.37318	0	0	75.0 - 125.0
Thallium	20	87.9	5.54313	0	0	75.0 - 125.0
Vanadium	20	90.4	4.17102	0	0	75.0 - 125.0
Zinc	20	92.3	9.06178	0	0	75.0 - 125.0
Nitrate by E353.2						
Matrix Spike Nitrate	21	97.5	20.05586	3	4	80.0 - 120.0
Orthophosphate						
Matrix Spike Orthophosphate	12	99.8	5.33493	0	0	80.0 - 120.0
Lead by SW7421						
Analytical Spike Lead	144	111.6	18.02823	1	26	75.0 - 125.0
Matrix Spike Lead	20	106.8	31.83077	2	6	75.0 - 125.0

(Continued)

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TABLE 4-9. (Continued)

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
Selenium by SW7740						
Analytical Spike Selenium	144	82.9	20.32919	34	0	75.0 - 125.0
Matrix Spike Selenium	20	74.1	29.35710	5	0	75.0 - 125.0
Sulfate						
Matrix Spike Sulfate	9	101.1	12.37053	0	0	80.0 - 120.0

TABLE 4-10. SUMMARY OF SURROGATE SPIKE RESULTS, CARSWELL AFB, TEXAS

SUMMARY OF SPIKE RESULTS FOR MATRIX = Groundwater

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
Halocarbons by EPA 601						
Surrogate Spike 1-Bromo-4-fluorobenzene	87	120.1	14.25544	0	6	40.0 - 140.0
Aromatics by EPA 602						
Surrogate Spike 1-Bromo-4-fluorobenzene	33	95.3	31.53735	3	2	40.0 - 140.0

Metals by SW846 Method 6010 (ICAP) -- Matrix spike recoveries for several metals by SW6010 indicated some bias and imprecision. Silicon recoveries were most heavily biased and imprecise (mean (standard deviation) = 177% (170%)) with eight of 20 recoveries greater than the acceptance limit of 125%. Calcium spike recoveries indicate calcium recoveries are biased low and are imprecise.

Nitrate by EPA Method 353.2 -- Matrix spike recoveries for nitrate by E353.2 indicate little bias but slightly greater imprecision than expected. Mean (std. dev.) recovery was 98% (22%). Three of 21 recoveries were below the lower acceptance criteria of 80% and four recoveries were greater than the upper acceptance criteria of 120%.

Halocarbons by EPA 601 -- Surrogate spike results for samples analyzed for halocarbons by EPA 601 indicate bias towards high recovery for 1-bromo-4-fluorobenzene. Mean recovery was 120% with six of 87 sample recoveries were greater than the acceptance criteria limit of 140%.

4.1.3.2 Surface Water Matrix

Generally, spike recoveries were within expected limits. Matrix and surrogate spike recoveries are presented in Table 4-11 and Table 4-12, respectively. Exceptions are discussed below by spike type and method.

Aromatics by EPA 602 -- Ten samples were spiked with the surrogate 1-bromo-4-fluorobenzene. Recoveries indicate a bias towards low recovery and high imprecision. Five recoveries were below acceptance criteria limits of 40%. Mean (standard deviation) percent recovery was 70% (52%).

Lead by SW846 Method 7421 -- Analytical spike recoveries for lead indicated bias and imprecision. Fourteen out of 24 samples had recoveries greater than the upper acceptance criteria of 125%. Analysis of QCCS and/or continuing calibration check samples indicated the system was in control and so no samples were reanalyzed.

TABLE 4-11. SUMMARY OF SPIKE RESULTS, CARSWELL AFB, TEXAS

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
ARSENIC BY SW7060						
Analytical Spike						
Arsenic	24	88.9	6.40864	0	0	75.0 - 125.0
MERCURY BY COLD VAPOR						
Analytical Spike						
Mercury	24	98.1	6.59326	0	0	75.0 - 125.0
ICP 25 ELEMENT SCAN						
Analytical Spike						
Aluminum	24	87.6	2.99153	0	0	75.0 - 125.0
Antimony	24	81.4	5.57882	0	0	75.0 - 125.0
Arsenic	24	100.8	2.84344	0	0	75.0 - 125.0
Barium	24	86.3	1.77544	0	0	75.0 - 125.0
Beryllium	24	87.2	1.80980	0	0	75.0 - 125.0
Boron	24	97.7	6.31538	0	0	75.0 - 125.0
Cadmium	24	84.7	1.98865	0	0	75.0 - 125.0
Calcium	24	90.6	4.12750	0	0	75.0 - 125.0
Chromium	24	85.2	3.33188	0	0	75.0 - 125.0
Cobalt	24	84.5	1.53167	0	0	75.0 - 125.0
Copper	24	84.9	2.55235	0	0	75.0 - 125.0
Iron	24	83.9	2.32036	0	0	75.0 - 125.0
Lead	24	82.4	3.22917	0	0	75.0 - 125.0
Magnesium	24	86.7	2.95865	0	0	75.0 - 125.0

(Continued)

TABLE 4-11. (Continued)

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
Manganese	24	83.3	1.73623	0	0	75.0 - 125.0
Molybdenum	24	85.5	1.44463	0	0	75.0 - 125.0
Nickel	24	85.0	3.56894	0	0	75.0 - 125.0
Potassium	24	86.0	3.34247	0	0	75.0 - 125.0
Selenium	24	86.9	2.87291	0	0	75.0 - 125.0
Silicon	24	98.8	3.90837	0	0	75.0 - 125.0
Silver	24	81.5	4.42326	0	0	75.0 - 125.0
Sodium	24	99.5	9.38073	0	0	75.0 - 125.0
Strontium	24	85.3	1.89393	0	0	75.0 - 125.0
Thallium	24	83.8	4.56812	0	0	75.0 - 125.0
Vanadium	24	85.7	2.88141	0	0	75.0 - 125.0
Zinc	24	86.5	2.58760	0	0	75.0 - 125.0
LEAD BY SW7431						
Analytical Spike						
Lead	24	121.1	20.10908	0	14	75.0 - 125.0
SELENIUM BY SW7740						
Analytical Spike						
Selenium	24	80.6	12.82632	10	0	75.0 - 125.0

TABLE 4-12. SUMMARY OF SURROGATE SPIKE RESULTS, CARSWELL AFB, TEXAS

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
HALOCARBONS BY EPA 601						
Surrogate Spike						
1-Bromo-4-fluorobenzene	16	114.4	13.69656	0	0	40.0 - 140.0
AROMATICS BY EPA 602						
Surrogate Spike						
1-Bromo-4-fluorobenzene	10	70.0	52.01282	5	0	40.0 - 140.0

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Selenium by SW846 Method 7740 -- Analytical spike recoveries for selenium indicated bias and imprecision. Ten out of 24 samples had recoveries less than the lower acceptance criteria of 75%.

Field QC Water Matrix

Spike recoveries were within expected limits. Matrix and surrogate spike recoveries are presented in Table 4-13 and Table 4-14, respectively.

Field and Matrix Duplicates

Variability can be assessed against several components of a sampling effort. For Carswell, sampling and analytical variability are the primary components of total variability. Since samples were collected over a short time period, temporal variability is assumed to be negligible. Also, the water systems are assumed to be fairly homogeneous at each location throughout the base, so spatial variability for any duplicate pair is assumed to be negligible. Using these assumptions, total variability is the variability due to the sample effort and analytical effort combined and as such indicate total measurement imprecision. Standard deviations and CVs for field duplicates and matrix spike duplicates are pooled to estimate total variability as a pooled standard deviation (pooled std. dev.) or pooled coefficient of variation (pooled CV).

Variability due to the analytical method can be estimated using predigestion duplicates. Although variability for these duplicates would include natural matrix effects as well as method preparation and analysis effects, comparison of predigestion duplicate results to field duplicate results and matrix spike duplicate results can provide information about the analytical system.

Total variability is discussed below for each method by matrix.

TABLE 4-13. SUMMARY OF SPIKE RESULTS, CARSWELL AFB, TEXAS

SUMMARY OF SPIKE RESULTS FOR MATRIX = Water (Field/Trip QC)

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
HALOCARBONS BY EPA 601						
Matrix Spike						
1,1-Dichloroethene	8	82.8	6.69221	0	0	28.0 - 167.0
Chlorobenzene	8	109.4	9.73855	0	0	38.0 - 150.0
Trichloroethene	8	114.6	37.97344	0	2	35.0 - 146.0
ARSENIC BY SW7060						
Analytical Spike						
Arsenic	14	90.9	8.33403	0	0	75.0 - 125.0
FLUORIDE BY EPA 340.2						
Matrix Spike						
Fluoride	2	97.7	1.07137	0	0	85.0 - 115.0
MERCURY BY COLD VAPOR						
Analytical Spike						
Mercury	14	95.4	6.69796	0	0	75.0 - 125.0
ICP 25 ELEMENT SCAN						
Analytical Spike						
Aluminum	14	91.4	2.49945	0	0	75.0 - 125.0
Antimony	14	84.5	3.56802	0	0	75.0 - 125.0
Arsenic	14	102.4	1.74154	0	0	75.0 - 125.0
Barium	14	88.7	1.68379	0	0	75.0 - 125.0

(Continued)

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TABLE 4-13. (Continued)

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
Barium	14	88.7	1.68379	0	0	75.0 - 125.0
Beryllium	14	89.6	1.86495	0	0	75.0 - 125.0
Boron	14	101.6	12.53676	0	0	75.0 - 125.0
Cadmium	14	86.6	1.90575	0	0	75.0 - 125.0
Calcium	14	94.8	4.11710	0	0	75.0 - 125.0
Chromium	14	86.8	1.84718	0	0	75.0 - 125.0
Cobalt	14	86.5	1.74312	0	0	75.0 - 125.0
Copper	14	87.4	1.69680	0	0	75.0 - 125.0
Iron	14	88.4	1.60357	0	0	75.0 - 125.0
Lead	14	82.9	2.47626	0	0	75.0 - 125.0
Magnesium	14	90.8	2.22498	0	0	75.0 - 125.0
Manganese	14	86.5	1.55662	0	0	75.0 - 125.0
Molybdenum	14	85.8	2.19014	0	0	75.0 - 125.0
Nickel	14	87.0	1.56893	0	0	75.0 - 125.0
Potassium	14	88.9	1.85904	0	0	75.0 - 125.0
Selenium	14	89.7	2.84006	0	0	75.0 - 125.0
Silicon	14	93.6	8.27149	0	0	75.0 - 125.0
Silver	14	86.9	2.64471	0	0	75.0 - 125.0
Sodium	14	92.0	5.33494	0	0	75.0 - 125.0
Strontium	14	88.4	1.73680	0	0	75.0 - 125.0
Thallium	14	84.9	4.12976	0	0	75.0 - 125.0
Vanadium	14	87.4	2.27746	0	0	75.0 - 125.0
Zinc	14	87.9	2.10703	0	0	75.0 - 125.0

(Continued)

TABLE 4-13. (Continued)

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
NITRATE BY E353.2						
Matrix Spike						
Nitrate	1	85.0		0	0	80.0 - 120.0
LEAD BY SW7421						
Analytical Spike						
Lead	14	111.1	9.49060	0	1	75.0 - 125.0
SELENIUM BY SW7740						
Analytical Spike						
Selenium	14	87.9	30.57013	2	0	75.0 - 125.0

TABLE 4-14. SUMMARY OF SURROGATE SPIKE RESULTS, CARSWELL AFB, TEXAS

SUMMARY OF SURROGATE SPIKE RESULTS FOR MATRIX = Water (Field/Trip QC)

Parameter	Number of Samples	Mean % Recovery	Standard Deviation	Number Below Acceptance Limits	Number Above Acceptance Limits	(Matrix) Acceptance Criteria
HALOCARBONS BY EPA 601						
Surrogate Spike						
1-Bromo-4-fluorobenzene	16	121.4	14.26826	0	1	40.0 - 140.0
AROMATICS BY EPA 602						
Surrogate Spike						
1-Bromo-4-fluorobenzene	3	91.7	3.05505	0	0	40.0 - 140.0

Ground Water

Generally, total variability for ground water was as expected. Little information was available from field duplicates since many analytes were not detected in samples. Also as expected, variability estimates indicate greater relative variability when concentrations are near detection limits and lesser relative variability when concentrations are significantly greater than detection limits. Methods or analytes with large variability are discussed below. Summarized results are presented in Table 5 of Appendix H.

Arsenic by SW7060 -- Sixteen pairs of matrix spike duplicates were analyzed for arsenic by Method SW7060. Variability was approximately 26% with four matrix spike results outside acceptance criteria. Results outside criteria suggest that although the average variability (pooled CV) was reasonable, results may sporadically be more imprecise than expected.

Two predigestion duplicate pairs were analyzed by SW7060 for arsenic. Mean recoveries ranged from "not detected" to 0.033 mg/L. Variability (expressed as CV%) was 33%.

Mercury by E245.1 -- Twelve field duplicate pairs were analyzed for mercury by Method E245.1. While variability was fairly high, pooled CV = 60%, it was not unreasonable because concentrations were very near detection limits. Results ranged from "not detected" to 0.0044 mg/L, concentrations at which relative variability is very great as compared to absolute variability.

Sixteen matrix spike duplicate pairs were analyzed for mercury by E245.1. Mean recoveries ranged from 87.5% to 105%. Variability was approximately 5%.

Lead by SW7421 -- Twelve field duplicates were analyzed for lead by Method SW7421. Mean concentrations ranged from both samples "not detected" to 0.81 mg/L. Variability (CV%) was 45%. Since these results are near the detection limit it is not unexpected for relative variability to be higher than expected.

Sixteen matrix spike duplicate pairs were analyzed for lead by Method SW7421. Mean percent recoveries were widely variable ranging from 23% to 132% with a pooled CV of 32%.

Two predigestion duplicate pairs were analyzed by SW7421 for lead. Mean recoveries ranged from 0.012 mg/L to 0.079 mg/L. Variability (expressed as CV%) was 89%.

Apparently, matrix affects contribute to variability but affect measurement imprecision less than overall variability.

Selenium by SW7740 -- Sixteen matrix spike duplicate pairs were analyzed for selenium by Method SW7740. Mean recoveries ranged from 39% to 96% with a pooled CV of 52%. At least one matrix spike recovery was less than acceptance criteria, thus increasing variability. Imprecision is assumed to be solely due to matrix effects.

Hydrocarbons by E418.1 -- Four field duplicate pairs were analyzed by Method E418.1 for hydrocarbons. Variability was greater than expected at 42%. However, mean concentrations ranged from "not detected" to only 8.5 mg/L. This relative variability may be due to concentration variability near the detection limit.

Two matrix spike duplicate pairs were analyzed for hydrocarbons by Method E418.1. Mean recoveries ranged from 88% to 90% with 7% variability.

Nitrate by E353.2 -- Three field duplicates were analyzed for nitrate by Method E353.2. Total variability was 41% for means ranging from 0.095 mg/L to 0.740 mg/L.

Surface Water

Where data was available, total variability for surface water was as expected. Little information was available from field duplicates since many analytes were not detected in samples. Matrix spike duplicates were not requested for surface water samples. Variability estimates indicate greater relative variability when concentrations are near detection limits and lesser relative variability when concentrations are significantly greater than detection limits. Methods or analytes with large variability are discussed below. Summarized results are presented in Table 5 of Appendix H.

Lead by SW7421 -- Two field duplicate pairs were analyzed for lead by Method SW7421 in surface water. Concentrations were very near detection limits and as expected relative variability was high (CV = 42%).

Metals by SW6010 (ICAP) -- Two field duplicate pairs were analyzed for metals by SW6010. Total variability could not be estimated for several analytes because of "not detected" results for all samples. Of the analytes that were detected, variability (expressed as CV%) ranged from 1% for strontium to 132% for chromium. As expected variability was greatest for analytes with concentrations near the detection limit.

Nitrate by E353.2 -- One field duplicate pair was analyzed by Method E353.2 for nitrate in surface water. Variability was 116%.

4.1.4 Sample Collection Quality Control

The QA effort for sample collection was successful and data capture complete. No samples were invalidated. Standard forms, methods, chain-of-custody and hold times were generally followed as specified. However, some chains-of-custody were not signed by the laboratory recipient.

4.1.4.1 Standard Forms

Standard forms taken from the Air Force IRP program were used to log sample collection. Standard, bound, log books (used to log field data associated with samples) and chain-of-custody forms (used to document custody of samples from time of collection to reporting analytical results) were used as specified in the QAPP. A discussion of the completeness of the sampling follows. Sample log forms were used to record sample inventory data (eg.

location data, sample type, matrix, etc.). This data was entered into the project database and the forms archived by the project geologist. Chain-of-custody forms were filled out at the time samples were shipped from the field to the lab and specified analyses to be performed on each sample, the relinquishing field team member, and the recipient for the laboratory. Some chain-of-custody forms were not signed upon receipt at the lab. Sample numbers and associated analyses are presented in Table 4-15.

While lack of a signature by a laboratory representative breaks the physical chain-of-custody it may be assumed samples were handled appropriately and results are valid estimates for chemical concentrations on each sample. This assumption of valid custody is possible due to laboratory practices which include a picture of the samples as received and sample tracking in the laboratory database. The laboratory database provides a valid means of recording sample custody up through reporting of results and sample disposal.

Three samples were not analyzed as directed. These were samples 392, 393, and 354. These samples were collected again during field efforts.

Standard Methods

Standard methods were used for sample collection. Standard methods used for chemical analysis were presented in Table 4-1.

Hold Times

Use of method-specified, standard, sample holding times controls variability caused by samples being analyzed after constituents have partially decomposed. Data regarding hold times (e.g., log data, date analyzed, specified maximum hold time and actual day until analysis) are provided in Table 6 in Appendix H. One sample was analyzed by Method 601 one day over the hold time of 14 days. This was sample 017. Trip blanks 050, 081, 093, 114, and 359, to be analyzed by Method 602, were analyzed between three and seven days over the seven day hold time. This problem does not invalidate results

TABLE 4-15. SAMPLES WITH UNSIGNED LABORATORY RECIPIENT CHAIN-OF-CUSTODY

Sample ID	Analysis Required
154	Chloride, Fluoride, TDS, NO_3. OPO_4, Metals
157	154 + MS
160	154 + MSD
163	Dissolved Metals, MS, MSD
168	Chloride, Fluoride, Sulfate, TDS
169	Nitrate, Orthophosphate
170	Total Metals
171	Dissolved Metals
174	Chloride, Fluoride, Sulfate, TDS
175	Chloride, Fluoride, Sulfate, TDS
176	Nitrate, Orthophosphate
177	Nitrate, Orthophosphate
178	Total Metals
179	Total Metals + Analytical Duplicate
180	Dissolved Metals
181	Dissolved Metals + Analytical Duplicate
354	Chloride, Fluoride, Sulfate, TDS
355	Nitrate, Orthophosphate
356	Total Metals
357	Dissolved Metals
358	Hydrocarbons
361	Chloride, Fluoride, Sulfate, TDS
362	Nitrate, Orthophosphate
363	Total Metals
364	Dissolved Metals
365	Hydrocarbons
367	Chloride, Fluoride, Sulfate, TDS
368	Nitrate, Orthophosphate
369	Total Metals
370	Dissolved Metals
371	Hydrocarbons
374	Chloride, Fluoride, Sulfate, TDS

of these trip blanks. As noted in the ITIR, trip blanks to be analyzed by Method 602 were not acid preserved. Because they were not acid preserved the hold times were seven days instead of 14 days as for the acid preserved field samples to be analyzed by Method 602. Trip blanks are used to identify contamination during shipping or during storage in the laboratory. Samples to be analyzed for purgeable aromatics by Method 602 are preserved to prevent biological degradation of the analytes of interest during storage (i.e., beyond the normal seven day holding time). Biological activity will depend on a number of factors, such as natural biological populations, concentration of compounds, mix of compounds, etc. Therefore, the extent to which the integrity of a given sample may be compromised by not analyzing within the seven day hold time for an unpreserved sample may vary. Historically, trip blanks for Method 602 analyses were not preserved so that the trip blank could be analyzed for Method 601 (where the sample is not acid preserved) or Method 602 as needed for a project. Since the preparation procedure for trip blanks renders the water practically sterile, it is generally assumed that bacterial populations will not expand to natural levels within 14 days and thus biological activity is minimal. Therefore, the results of these trip blanks are considered usable and provide information about potential shipping and handling contamination. However, it is recognized that as a worst-case situation the Method 602 results of these trip blanks may be falsely low (i.e., a false-negative result) due to biological degradation. And, as such, low-level concentrations in natural samples shipped with these trip blanks may in fact be due to shipping contamination. Natural samples possibly affected are:

- TB 050: 044, 051, 063, 069, 070,
- TB 093: 087, 094, 100,
- TB 114: 108, 115, 121, 127, 128, 129, 140.

No results are invalidated due to hold time violation.

Concentrations of compounds in natural matrix samples should be considered suspect as a false-positive if less than the maximum concentrations depicted in Table 4-9.

4.2 Results of Ground-Water and Surface Water Analyses

Ground-water samples from thirty-five wells were collected during April and May 1990 for laboratory analysis. Seven surface water samples were also collected. Since contamination was previously found to exist only in those wells screened in the Upper Zone Aquifer, all ground-water samples were collected from Upper Zone monitor wells. Figure 4-1 depicts the locations of all of the most recent water sampling sites at the Flightline Area. Each sample was submitted to Radian's laboratories for analysis of the organic and inorganic constituents listed in Table 4-16. Both organic and inorganic constituents exceeding EPA drinking water standards (Maximum Contaminant Levels, or MCLs) had been detected in the Flightline Area in past sampling efforts. An Informal Technical Information Report (ITIR) with analytical summary tables, QA/QC data, sample cross-reference tables and chain-of-custody forms for the recent ground-water investigation at the Flightline Area was provided to the U. S. Air Force HSD IRP Program Office in September 1990 (Radian 1990d). Following is a brief summary of the quality assurance/quality control (QA/QC) results for most recent Carswell AFB ground-water sampling.

4.2.1 Ground-Water Contamination

As indicated in previous Flightline Area sampling efforts, TCE was the principal contaminant detected which exceeded EPA primary standards. The only other organic constituent found to exceed federal standards was vinyl chloride. Two organic compounds were detected in ground water with concentrations exceeding EPAs MCLs; these included tetrachloroethene and cis-1,2-dichloroethene.

Four inorganic compounds exceeded federal primary drinking water standards in the most recent water sampling. Chromium was found in excess of the respective MCL in three monitor wells. Lead, arsenic and mercury were found in concentrations exceeding the respective MCLs in one well each.

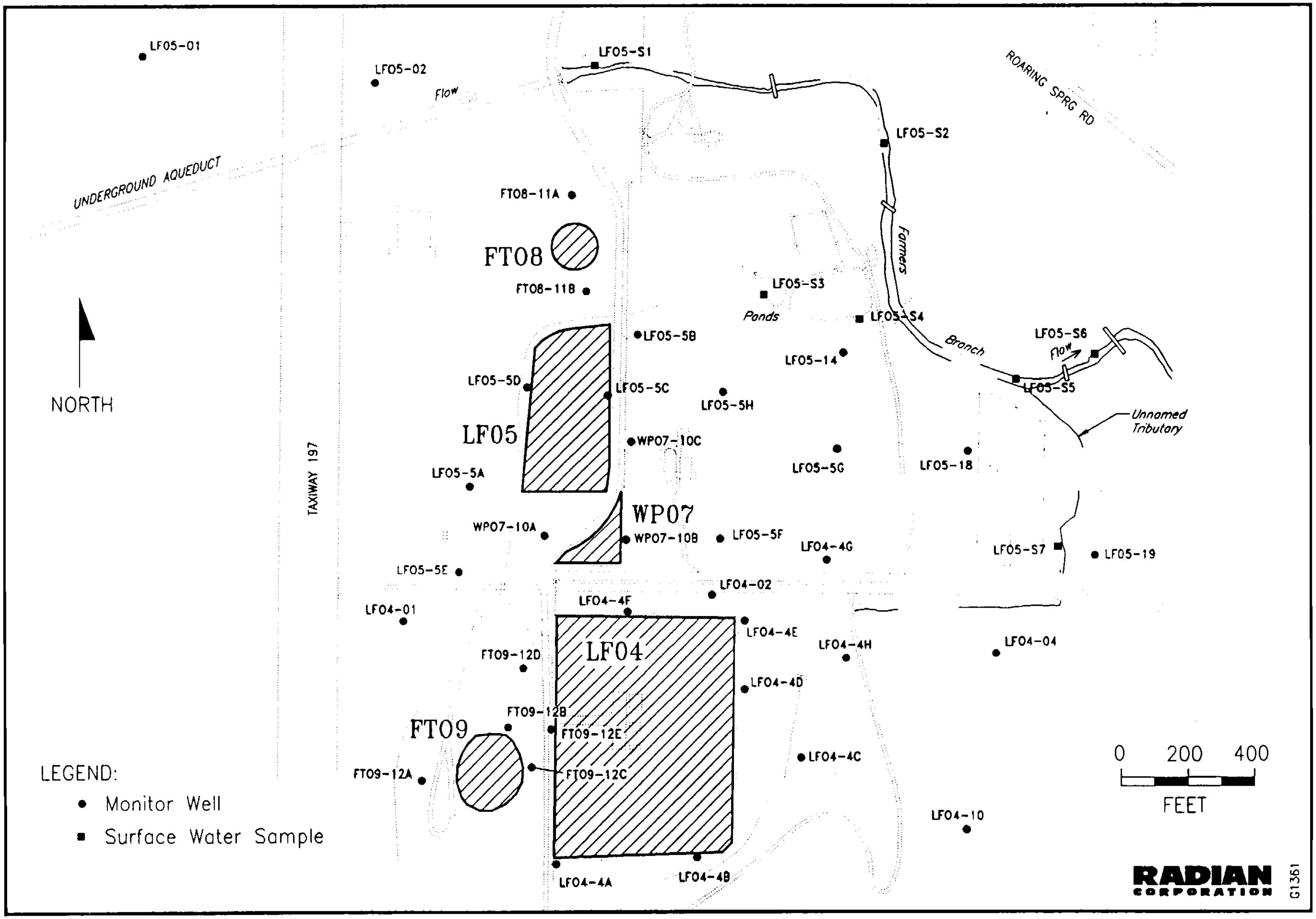

Figure 4-1. Locations of 1990 Ground-Water and Surface Water Samples, Flightline Area, Carswell AFB, Texas

TABLE 4-16. SUMMARY LISTING OF ORGANIC AND INORGANIC ANALYTES, FLIGHTLINE AREA, CARSWELL AFB, TEXAS

	Inorganic Parameters	
Organic Parameters	Metals	Non-Metals
1,1,1-Trichloroethane	Aluminum	Chloride
1,1,2,2-Tetrachloroethane	Antimony	Fluoride
1,1,2-Trichloroethane	Arsenic	Nitrate as N
1,1-Dichloroethane	Barium	Orthophosphate
1,1-Dichloroethene	Beryllium	Sulfate
1,2-Dichlorobenzene	Boron	Total Dissolved Solids
1,2-Dichloroethane	Cadmium	
1,2-Dichloropropane	Calcium	
1,3-Dichlorobenzene	Chromium	
1,4-Dichlorobenzene	Cobalt	
2-Chloroethylvinyl ether	Copper	
Bromodichloromethane	Iron	
Bromoform	Lead	
Bromomethane	Magnesium	
Carbon tetrachloride	Manganese	
Chlorobenzene	Mercury	
Chloroethane	Molybdenum	
Chloroform	Nickel	
Chloromethane	Potassium	
Dibromochloromethane	Selenium	
Methylene chloride	Silicon	
Tetrachloroethene	Silver	
Trichloroethene	Sodium	
Trichlorofluoromethane	Strontium	
Vinyl chloride	Thallium	
cis-1,2-Dichloroethene	Vanadium	
cis-1,3-Dichloropropene	Zinc	
trans-1,2-Dichloroethene		
trans-1,3-Dichloropropene		

Contamination detected in the ground water of the Flightline Area is limited to the Upper Zone Aquifer. The low permeability limestone of the underlying Goodland/Walnut aquitard underlies the Upper Zone Aquifer. No Flightline Area monitor wells are completed in the aquitard as past drilling in the Goodland and Walnut Formations has shown the formations to be non-water bearing. Ground-water samples from the Paluxy Aquifer, which underlies the Goodland/Walnut aquitard in the Flightline Area, have had no detections of contaminants. Therefore, the vertical extent of organic compound contamination in the Flightline Area corresponds to the upper surface of the Goodland/Walnut aquitard.

A detailed discussion of the pertinent organic and inorganic constituents and ground-water quality indicators follows.

4.2.1.1 Organic Ground-Water Contaminants

Table 4-17 summarizes the findings of the laboratory analyses for organic constituents in Flightline Area monitor wells, with respect to primary drinking water standards (MCLs). TCE exceeded the MCL in 27 of the 35 wells sampled. Vinyl chloride exceeded the MCL in seven wells.

Tetrachloroethene (PCE) was detected in a total of six wells, and exceeded the MCLs in three wells. The proposed MCL for cis-1,2-dichloroethene was exceeded in samples from 23 of the monitor wells in the Flightline Area. This compound was detected in 30 of 35 wells in the Flightline Area. Trans-1,2-dichloroethene, another isomer of dichloroethene, was also detected frequently in the Flightline Area, but at significantly lower concentrations than the cis- isomer. The MCLs (100 μg/L) for the trans- isomer was never exceeded by Flightline Area water samples.

Following is a more detailed discussion of organic constituents detected in the ground water of the Flightline Area.

TABLE 4-17. SUMMARY OF ORGANIC GROUND-WATER SAMPLING RESULTS, SPRING 1990, CARSWELL AFB, TEXAS

Analytical Parameter	EPA Standards or Proposed Standards* (µg/L)	Range of Detection Limits	Range of Concentrations of Constituents Detected	Total Number of Samples: Analyses for Constituent (No. of Wells)	Total Number of Samples: With Constituent Detected and Second Column Confirmation (No. of Wells)	Total Number of Samples: Exceeding EPA MCL/PMCL (No. of Wells)
Purgeable Halocarbons (601) µg/L						
1,1,1-Trichloroethane	200 (M)	0.2-50	0.37-0.70	74 (35 + 2 dup)	3 (3)	0
1,1,2,2-Tetrachloroethane		0.15-38	ND	74 (35)	0	0
1,1,2-Trichloroethane		0.2-50	ND	74 (35)	0	0
1,1-Dichloroethane		0.5-120	1.1	74 (35)	1 (1)	0
1,1-Dichlorethene	7 (M)	0.2-50	1.3-1.5	74 (35)	2 (2)	0
1,2-Dichlorobenzene	600 (P)	0.5-120	ND	74 (35)	0	0
1,2-Dichloroethane	5 (M)	0.1-25	ND	74 (35)	0	0
1,2-Dichloropropane	5 (P)	0.1-25	ND	74 (35)	0	0
1,3-Dichlorobenzene		0.32-80	ND	74 (35)	0	0
1,4-Dichlorobenzene	75 (M)	0.24-60	9.6	74 (35)	1 (1)	0
2-Chloroethylvinyl ether		0.5-130	ND	74 (35)	0	0
Bromodichloromethane		0.1-25	ND	74 (35)	0	0
Bromoform		0.5-130	ND	74 (35)	0	0
Bromomethane		1.2-300	ND	74 (35)	0	0
Carbon tetrachloride	5 (M)	0.12-30	ND	74 (35)	0	0
Chlorobenzene		0.25-63	2.3	74 (35)	1 (1)	0
Chloroethane		0.52-130	1.8	74 (35)	1 (1)	0
Chloroform		0.1-25	ND	74 (35)	0	0
Chloromethane		0.3-75	ND	74 (35)	0	0
Dibromochloromethane		0.2-50	ND	74 (35)	0	0
Methylene chloride		0.4-100	64-90	74 (35)	2 (2)	0
Tetrachloroethene	5 (P)	0.1-25	0.55-30	74 (35)	6 (6)	3 (3)
Trichloroethene	5 (M)	0.2-50	0.56-4400	74 (35)	32 (3)	29 (27)
Trichlorofluoromethane		0.2-50	ND	74 (35)	0	0
Vinyl chloride	2 (M)	0.2-50	6.2-170	74 (35)	8 (7)	8 (7)
cis-1,2-Dichloroethene	70 (P)	0.2-50	0.37-730	74 (35)	32 (30)	23 (22)
cis-1,3-Dichloropropene		0.2-50	ND	74 (35)	0	0
trans-1,2-Dichloroethene	100 (P)	0.2-50	0.72-44	74 (35)	6 (6)	0
trans-1,3-Dichloropropene		0.34-85	ND	74 (35)	0	0

*EPA standards are designated: M - Maximum Contaminant Level (MCL) and P - Proposed Maximum Contaminant Level (PMCL).

Trichloroethene

Figure 4-2 depicts an isoconcentration contour map of the trichloroethene (TCE) plume as it was detected in the Spring, 1990 sampling effort in the Flightline Area. The concentration of TCE in the ground water was reported at maximum levels in monitor wells LF04-4G and LF04-02, with detected values of 4400 and 4000 micrograms per liter (μg/L), respectively. The defined TCE plume has an aerial extent of approximately 50 acres, with most of the contamination underlying the base golf course. The limits of the plume are fairly well defined laterally, but not in the upgradient and downgradient directions (the extreme eastern and western portions of the Flightline Area). In the west, a concentration of 2700 μg/L was detected in monitor well LF05-01, with no accompanying upgradient well analyses to allow for contaminant concentration contouring in the western direction. Detected concentrations of 1200 and 1300 μg/L TCE in monitor well LF05-5A and LF05-5E, located hydraulically upgradient of Landfill 5 but with no near upgradient wells, prevents definition of the TCE plume along that upgradient edge. The ground-water flow direction (Figure 3-12) in the vicinity of monitor well LF05-01 is away from wells LF05-5A and LF05-5E, suggesting that contaminant plume migration deviates somewhat from the general ground-water flow pattern. Therefore, the contamination observed in monitor well LF05-01 could be continuous with that detected in LF05-5A and LF05-5E, but insufficient data from the intervening area make such a correlation speculative. Evidence of "black staining" at 39.5 feet in the log of borehole LF05-15, located between wells LF05-01 and LF05-5E, may be evidence of the TCE contamination being continuous between the wells. The TCE plume appears to intersect Farmers Branch (Figure 4-2) in the northeastern portion of the Flightline Area.

Figure 4-3 is a thickness map of the sand and gravel deposits in the Flightline Area. The thick sand and gravel sequences evident on a east-west linear trend through the Flightline Area are thought to represent a paleochannel, which is the depositional remains of a former stream channel. Past reports have suggested that, due to the greater density of TCE with respect to water, coupled with the increase in available porosity and permeability, the contamination will tend to migrate preferentially along

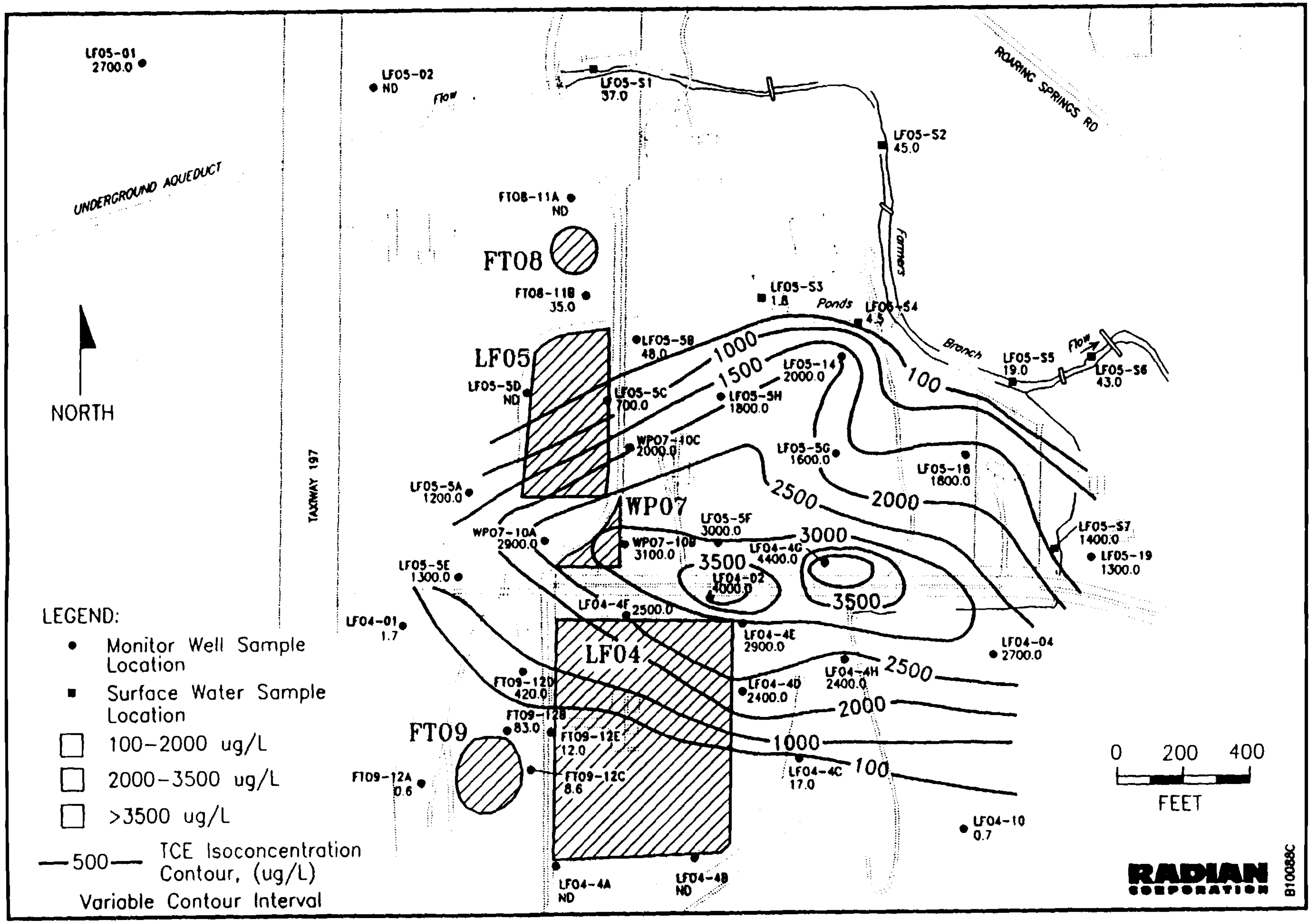

Figure 4-2. TCE Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas (Based on Spring, 1990 Water Sampling)
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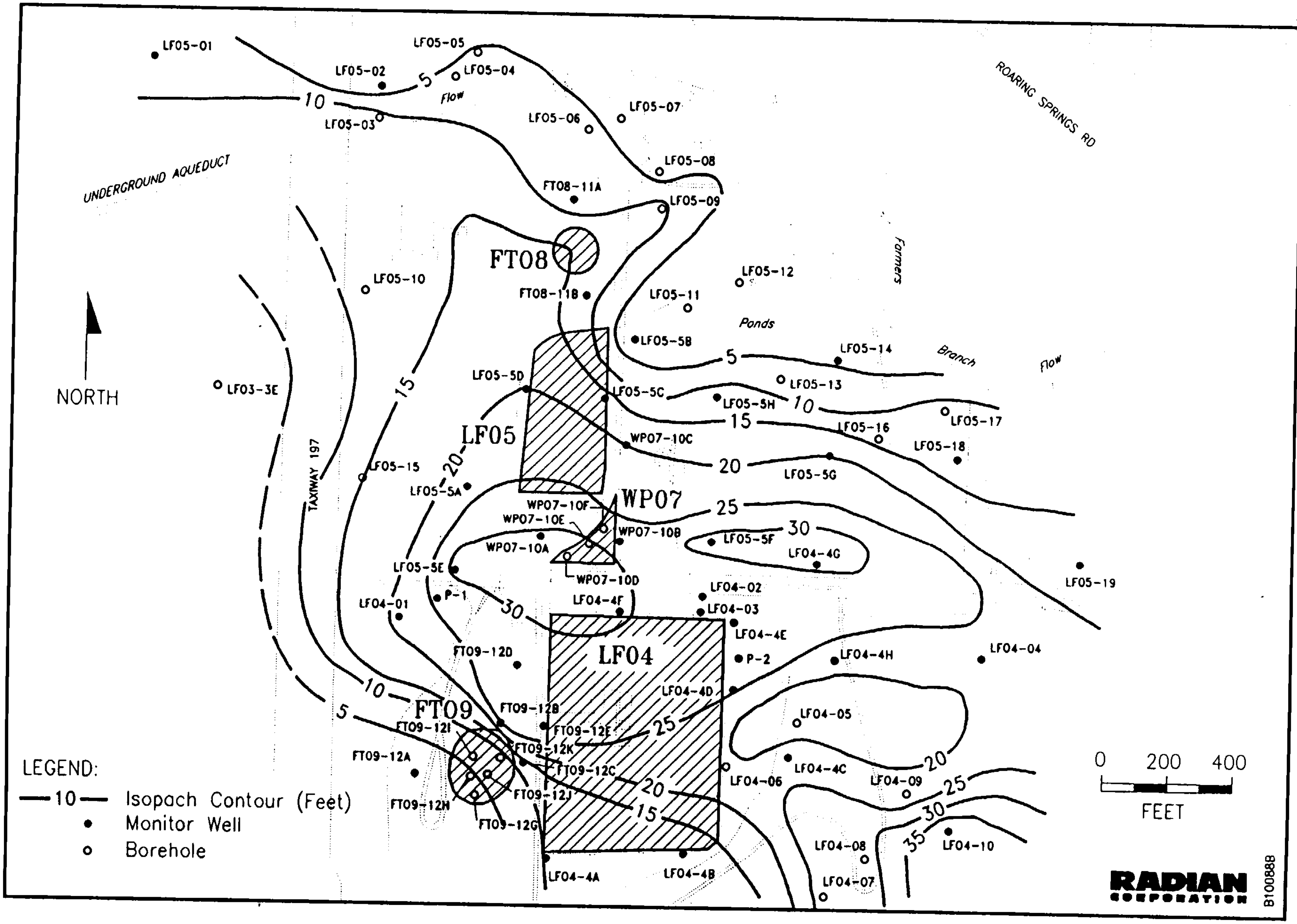

Figure 4-3. Sand and Gravel Isopach Map, Flightline Area, Carswell AFB, Texas

paleochannels filled with basal sands and gravels. When compared to the isoconcentration map of the TCE plume (Figure 4-2) this preferential migration is clearly evident, as the configuration of the plume and the zone of maximum concentrations closely resembles the location and configuration of the thickest Upper Zone sand and gravel sequences. Also of importance is the pattern of the relatively thick sand and gravels on the western side of the Flightline Area sites. Although data are sparse in the northwestern portion of Figure 4-3, it appears the thicker sands and gravels might trend westward on a line just south of LF05-01. The bedrock surface (Figure 3-3) is also relatively low in the vicinity of LF05-01. Both of these situations make the likelihood greater that contamination detected in monitor well LF05-01 is continuous with that in wells LF05-5A and LF05-5E.

The center of the TCE plume appears to be bimodal and is located hydraulically downgradient from Landfill 4, with TCE concentrations above 3000 μg/L covering an area of approximately 6.5 acres. The apex of the TCE plume does appear to have shifted since the last ground-water sampling effort, which took place in April 1988. Figure 4-4 represents an isoconcentration contour map of the results of the April, 1988 ground-water sampling. By comparing the plume shape and concentration distribution shown on the April, 1988 isoconcentration map with that on the Spring, 1990 map, the plume appears to have migrated in an easterly, hydraulically downgradient direction. In addition, the maximum concentration observed between the two sampling efforts has decreased, from 6400 μg/L in April 1988 to 4400 μg/L in the most recent analysis. The potential significance of this decrease with respect to the fate and transport of the contaminants in the ground water will be discussed in Section 5 of this report. While the migration and degradation of the plume is consistent with the physiologic and hydrogeologic setting of the Flightline Area and the nature of the contaminant, some degree of analytical variability is inherent between any two laboratory analyses occurring over time. Continued monitoring of the wells in the Flightline Area will be necessary to confirm apparent trends in contaminant migration.

Multiple sources have been postulated for the organic contamination found in the subsurface in the Flightline Area. The disposal methods and

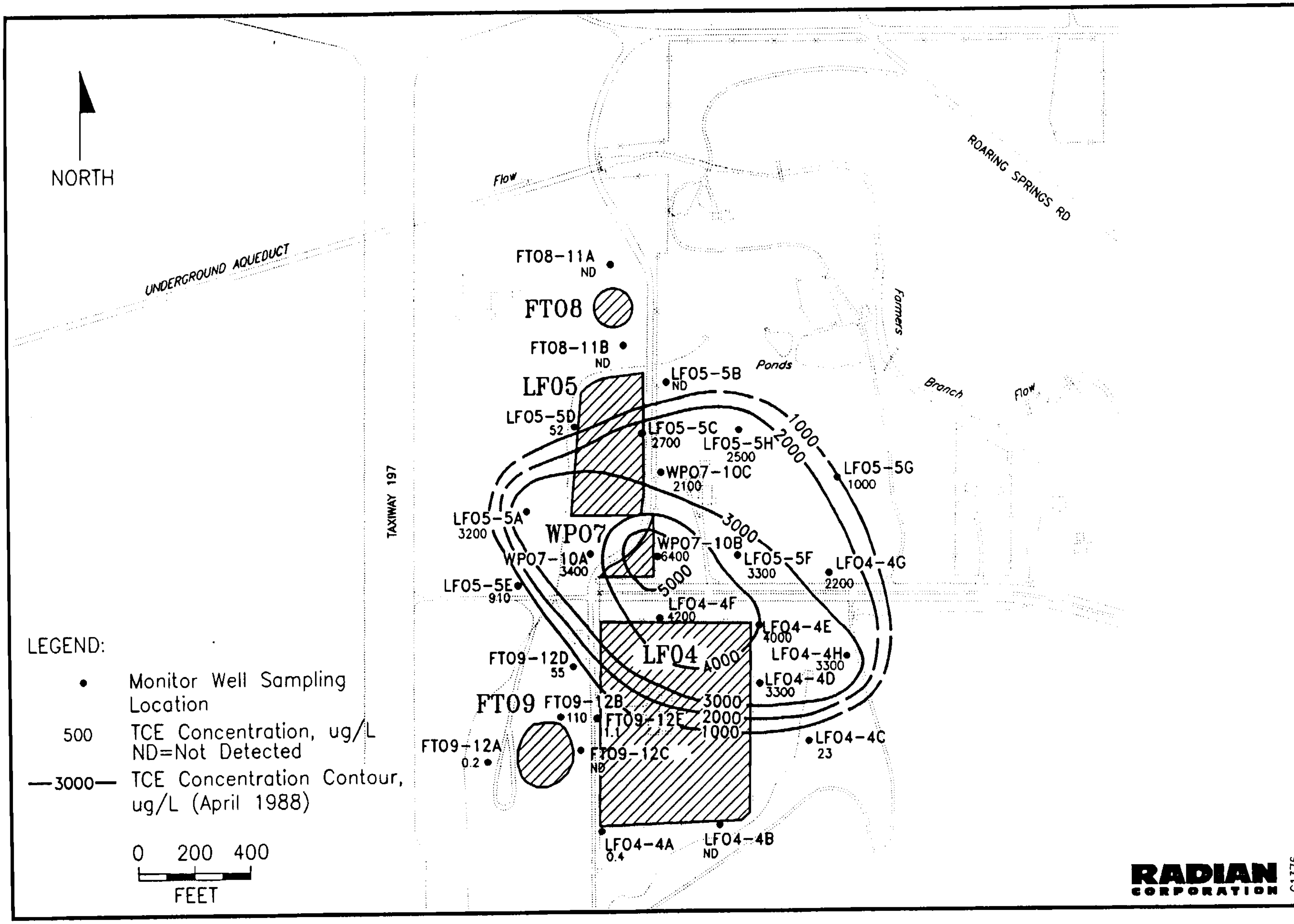

Figure 4-4. Contour Map of TCE Concentrations (> 1,000 μg/L) in Upper Zone Ground Water (April 1988), Flightline Sites, Carswell AFB, Texas

types of waste material believed to be present at Landfills 4 and 5 (LF04 and LF05) and the Waste Burial Area (WP07) are consistent with the types and amounts of contamination observed in downgradient wells. In addition, it is reasonable to assume that infiltration of some residual flammable solvents associated with the fire training activities at Site FT09 has occurred. Repeated evidence of TCE contamination in monitor wells located hydraulically upgradient of these sites indicates the existence of additional upgradient source(s). In the 1990 sampling, TCE concentrations of 1300 μg/L and 1200 μg/L were detected in monitor wells LF05-5E and LF05-5A, respectively, located upgradient to Landfill 5.

Air Force Plant 4 has been identified in past reports (Radian, 1986; Radian, 1989) as the probable upgradient source, but limited well control and lack of contemporaneous analytical data from the western and northwestern Flightline Area preclude this interpretation. A TCE concentration of 2700 μg/L in monitor well LF05-01, in the extreme northwestern portion of the Flightline Area (Figure 4-2) supports the existence of a significant source to the northwest. Further evidence is provided by the contamination detected around Site FT08. Monitor well FT08-11B was found to contain 35 μg/L TCE. While this well is downgradient to the site, no contamination was detected in previous sampling efforts, and the site is not considered a contributor to the main TCE plume.

Contamination in the subsurface associated with Site FT09 was not considered associated with the primary TCE plume in the RI/FS Stage 2 report. Evidence cited included the absence of ground water in boreholes beneath the site and ground-water contamination being limited to monitor wells which potentially receive runoff from the site. During the most recent investigation, TCE contamination was detected in each of the three wells at the site, suggest that, whatever the actual source, the contamination can be logically addressed along with the principal TCE plume for the purpose of this report. As with the other Flightline Area sites, the contamination may have resulted from activities conducted at the site, or may be from an upgradient source.

There is significant evidence of one or more upgradient, non-Flightline Area source of TCE contamination in the shallow ground water. Some increases in TCE concentrations in the ground water as it moves downgradient through the Flightline Area are probably related to the historical variability of detected TCE levels. However, the concentration distribution also suggests wastes previously disposed of in the waste burial area and/or landfills are contributing some additional component to the overall contaminant plume. There is especially strong evidence of a TCE contribution from the waste burial area (Site WP07) as the TCE concentration highs shown in Figure 4-2 are located directly downgradient of the site.

Vinyl Chloride

Vinyl chloride was the second most dominant contaminant in the Flightline Area, exceeding the MCLs in seven wells. Figure 4-5 illustrates an isoconcentration map of the vinyl chloride concentrations in the Flightline Area. Unlike the TCE plume, the vinyl chloride plume appears to be composed of several smaller zones of contamination, with the principal area being associated with Landfill 5.

Each of the wells in the main plume in which the vinyl chloride was detected is immediately hydraulically downgradient of Site LF05. The maximum concentration of vinyl chloride detected in the Flightline Area was 170 μg/L in monitor well LF05-5C. This well constitutes the apex of the main plume. Lesser amounts were detected in LF05-5B and WP07-10C, with 160 μg/L and 49 μg/L, respectively. Vinyl chloride was also detected in this area in the April, 1988 ground-water sampling effort. None of the sampled monitor wells located hydraulically upgradient of Site LF05 contained vinyl chloride, suggesting Site LF05 is the source of the main Flightline Area vinyl chloride plume.

Four additional wells contained vinyl chloride above the EPA MCL. Well LF04-4C contained vinyl chloride at 13 μg/L, which is a higher concentration than was detected in the April 1988 sampling, in which 3.8 μg/L was

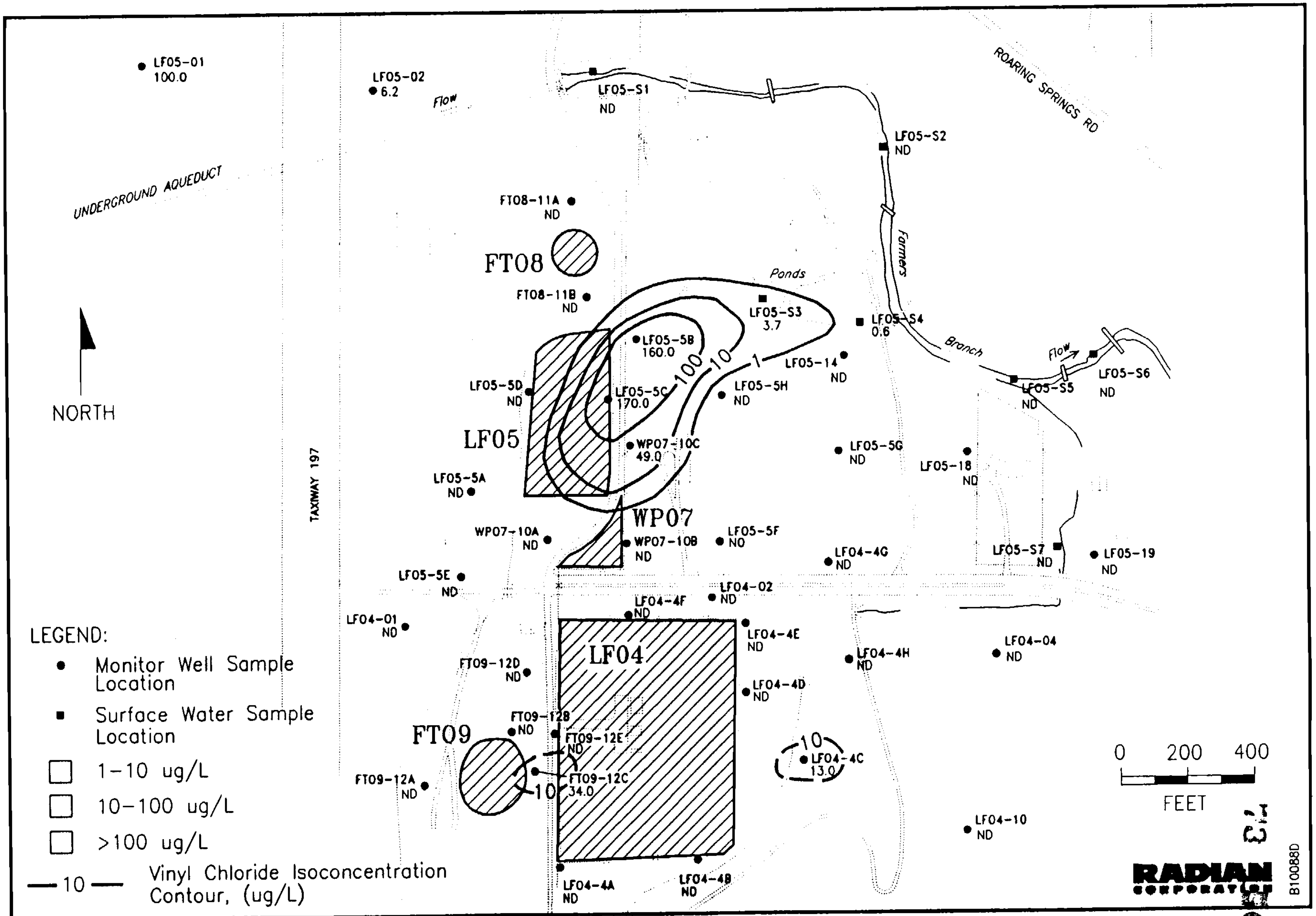

Figure 4-5. Vinyl Chloride Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas (Based on Spring, 1990 Water Sampling)
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detected. This is the only well downgradient from Site LF04 in which vinyl chloride has been detected. Vinyl chloride was also detected in LF05-01 (100 μg/L), and LF05-02 (6.2 μg/L), again suggesting a contaminant source upgradient from the Flightline Area. Since vinyl chloride may be a primary contaminant or one of the daughter products of TCE and multiple sources have been postulated for the contaminants present in the Flightline Area, it is difficult to pinpoint the exact source(s) of the vinyl chloride present in any individual well. The chemical inter-relationship between vinyl chloride, TCE and the other organic contaminants detected in the Flightline Area is discussed in Section 5.

Tetrachloroethene

The presence of tetrachloroethene (PCE) was confirmed in six monitor wells in the Flightline Area. The EPA PMCL of 5.0 μg/L was exceeded in three of these six wells. Due to the limited number of PCE detections in the Flightline Area ground water, an isoconcentration map was not prepared. Table 4-18 provides the laboratory results showing levels of PCE detected in each of the six monitor wells.

Two of the three wells found to exceed the PMCL for PCE were at Site FT09 (FT09-12B and FT09-12C). Monitor well FT09-12B had the highest confirmed level of PCE at 30 μg/L. PCE was not detected at this site during the April, 1988 sampling event. However, because PCE can be a precursor of TCE, the PCE contamination detected in the Flightline Area is probably related to the TCE and will be discussed in conjunction with the TCE plume in this report.

Total-1,2-Dichloroethene

The presence of cis-1,2-dichloroethene (cis-1,2-DCE) was confirmed in thirty monitor wells in the Flightline Area, with concentrations ranging from 0.37 μg/L to 730 μg/L. Trans-1,2-dichloroethene (trans-1,2-DCE) was confirmed in six wells, with concentrations ranging from 0.72 to 44.0 μg/L.

TABLE 4-18. SUMMARY OF GROUND-WATER SAMPLES WITH CONFIRMED CONCENTRATIONS OF TETRACHLOROETHENE, SPRING 1990, CARSWELL AFB, TEXAS

Well Number	Tetrachloroethene Concentration (μg/L)
LF04-4C	3.1
LF05-02	0.55
LF05-19	17.0
FT09-12B	30.0
FT09-12C	8.1
FT09-12E	0.82

Trans-1,2-DCE was detected only in wells in which cis-1,2-DCE was also detected. Because trans-1,2-DCE and cis-1,2-DCE are isomers, they will be considered together as part of the total-1,2-DCE plume.

Figure 4-6 illustrates an isoconcentration contour map for 1,2-DCE in the Flightline Area. As in the case of the TCE isoconcentration contour map, the apex of the plume is bimodal. The two 1,2-DCE nodes are located hydraulically downgradient of LF04 and LF05, respectively, and each is of the same relative magnitude of concentration. Further similarity to the TCE plume includes a lack of definition in the eastern and western margins of the plume. Monitor well LF05-01, in the extreme northwest portion of the Flightline Area, had a detected level of 1,2-DCE of 240 μg/L. This level of contamination, coupled with multiple confirmed detections of 1,2-DCE in wells immediately upgradient from sites LF04 and LF05, strongly support the presence of an upgradient contamination source. A confirmed detection of 540 μg/L of 1,2-DCE in monitor well LF04-04, in the southeastern portion of the Flightline Area, again makes it impossible to enclose contaminant contours in that area with confidence.

Other Organic Contaminants

Several other purgeable halocarbons were detected in the ground water in the Flightline Area (Table 4-17). These include 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, 1,4 dichloro-benzene, chlorobenzene, chloroethane, and methylene chloride. None of these compounds were detected in levels exceeding current EPA standards.

4.2.1.2 Inorganic Ground-Water Constituents

Four inorganic constituents, arsenic, mercury, chromium and lead, identified in the shallow Flightline Area ground water exceeded MCLs in unfiltered samples. However, based on the nature of the metal occurrences, they are not considered indicative of a ground-water contaminant problem at the site. Following is a discussion of inorganic contaminants detected in the shallow ground water of the Flightline Area.

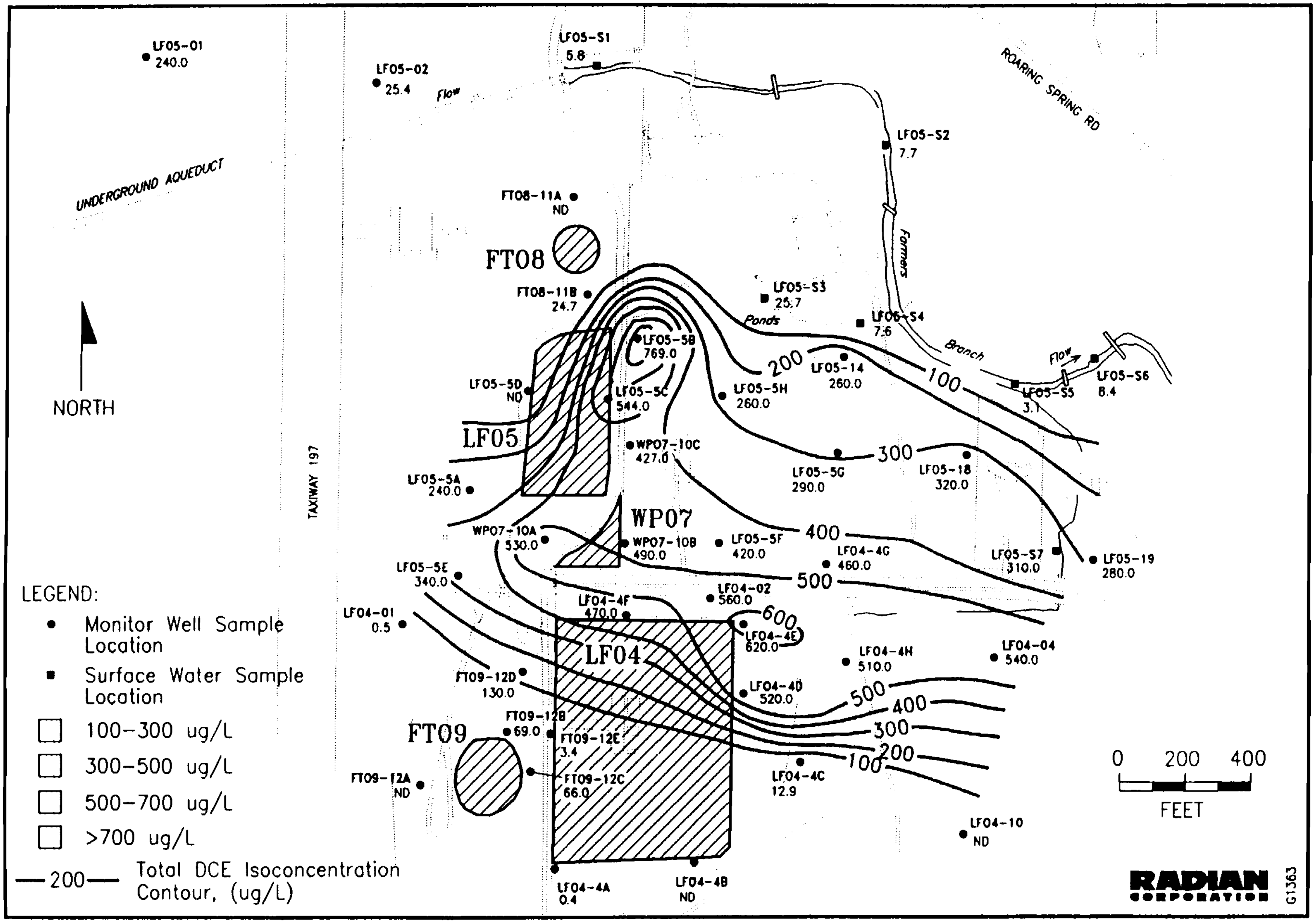

Figure 4-6. Total-1,2-Dichloroethene Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas (Based on Spring, 1990 Water Sampling)
Note: Figure will be colored in Final Report

4.2.1.3 Metals

Total arsenic and mercury were each detected above MCL values in unfiltered samples from single monitor wells in the Flightline Area. Table 4-19 shows the metals detected above MCLs. Total arsenic (MCL = 0.05 mg/L) narrowly exceeded the limit (by 0.003 mg/L) in the well in which it was detected (LF05-02). Total mercury exceeded the MCL by 0.0042 mg/L in FT09-12D. Total Arsenic was detected in concentrations above the MCL in eight monitor wells in the Flightline Area during the April 1988 sampling, but mercury was not detected.

Total lead was found to exceed the MCL of 0.05 mg/L in two monitor wells in the Spring 1990 sampling effort, as compared with total concentrations above the MCL in eight wells in the April 1988 sampling. Total chromium exceeded the MCL of 0.05 mg/L in three wells in the Spring 1990 sampling, as compared with twelve in 1988. No two total metals concentrations were found above established MCLs in the same well. The total lead contamination detected in monitor wells LF05-01 and LF05-14 exceeded federal standards by a maximum of 0.021 mg/L. Total chromium was detected at a maximum of 0.15 mg/L above federal standards in monitor well FT08-11A.

Figure 4-7 depicts the locations of the seven wells in which MCLs for total metals were exceeded. The random distribution of the contaminants makes delineation of a specific source difficult. Multiple man-made, as well as natural sources are possible for the detected metal concentrations. In general, the metal concentrations detected in Flightline Area wells were less than those reported from previous sampling events. Metals such as cadmium and barium, detected in several wells at total concentrations exceeding MCLs in the April 1988 sampling event, were not detected at levels above MCLs in any wells in the Spring 1990 sampling effort.

As stated above, no two metals were detected in excess of MCLs in the same well. In addition, in each case where a MCL was exceeded, the reported concentration was for total rather than dissolved metal. Total metal

TABLE 4-19. SUMMARY OF INORGANIC GROUND-WATER SAMPLING RESULTS, SPRING 1990, CARSWELL AFB, TEXAS

				Total Number of Samples		
Analytical Parameter	EPA Standard (MCL)* (mg/L)	Range of Detection Limits	Range of Concentrations of Constituents Detected	Analyses for Constituent (No. of Wells)	With Constituent Detected (No. of Wells)	Exceeding EPA MCL (No. of Wells)
Metals						
Aluminum		0.20-0.40	0.23-52	74 (35)	39 (35)	0
Antimony		0.10-0.11	ND	74 (35)	0	0
Arsenic	0.05 (M)	0.004-0.33	0.0041-0.053	148(35)	32 (24)	1 (1)
Barium	1.0 (M)	0.01-0.011	0.07-0.47	74 (35)	74 (35)	0
Beryllium		0.002-0.0022	0.003-0.004	74 (35)	2 (2)	0
Boron		0.60-0.66	0.061-0.92	74 (35)	4 (4)	0
Cadmium	0.01 (M)	0.005-0.0055	ND	74 (35)	0	0
Calcium		1.00-2.00	99-740	74 (35)	74 (35)	0
Chromium	0.05 (M)	0.01-0.011	0.015-0.20	74 (35)	13 (12)	3 (3)
Cobalt		0.01-0.011	0.012-0.039	74 (35)	12 (9)	0
Copper	--	0.02-0.022	0.024-0.047	74 (35)	9 (7)	0
Iron	--	0.04-0.044	0.041-61	74 (35)	62 (35)	0
Lead	0.05 (M)	0.003-0.055	0.003-0.09	148 (35)	55 (34)	2 (2)
Magnesium		1.00-1.10	3.4-20	74 (35)	74 (35)	0
Manganese	--	0.01-0.11	0.012-5.00	74 (35)	60 (35)	0
Mercury	0.002 (M)	0.0002-0.0018	0.0025-0.0062	74 (35)	2 (2)	1 (1)
Molybdenum		0.05-0.055	ND	74 (35)	0	0
Nickel		0.02-0.022	0.022-0.12	74 (35)	12 (12)	0
Potassium		3.00-3.30	0.031-10	74 (35)	20 (13)	0
Selenium	0.010 (M)	0.005-0.33	ND	148 (35)	0	0
Silicon		1.00-1.10	4.2-110	74 (35)	74 (35)	0
Silver	0.05 (M)	0.01-0.11	0.011-0.027	74 (35)	10 (8)	0
Sodium		1.00-1.10	10-102	74 (35)	74 (35)	0
Strontium		0.003-0.0033	0.029-1.1	74 (35)	74 (35)	0
Thallium		0.10-0.11	ND	74 (35)	0	0
Vanadium		0.02-0.022	0.025-0.013	74 (35)	16 (14)	0
Zinc	--	0.02-0.22	0.024-0.012	74 (35)	59 (31)	0
Non-Metals						
Chloride	--	1.00-1.00	5.1-71	74 (35)	37 (35)	0
Fluoride	4.0 (M)	0.10-0.10	0.2-1.0	74 (35)	37 (35)	0
Nitrate as N		0.02-0.20	0.024-6.4	74 (35)	37 (35)	0
Orthophosphate		0.01-0.01	0.011-0.057	74 (35)	10 (9)	0
Sulfate		0.20-20.0	2.2-140	74 (35)	37 (35)	0
Total Dissolved Solids		9.00-9.00	9.0-760	74 (35)	37 (34)	0

*EPA standard is designated: M - Maximum Contaminant Level (MCL).

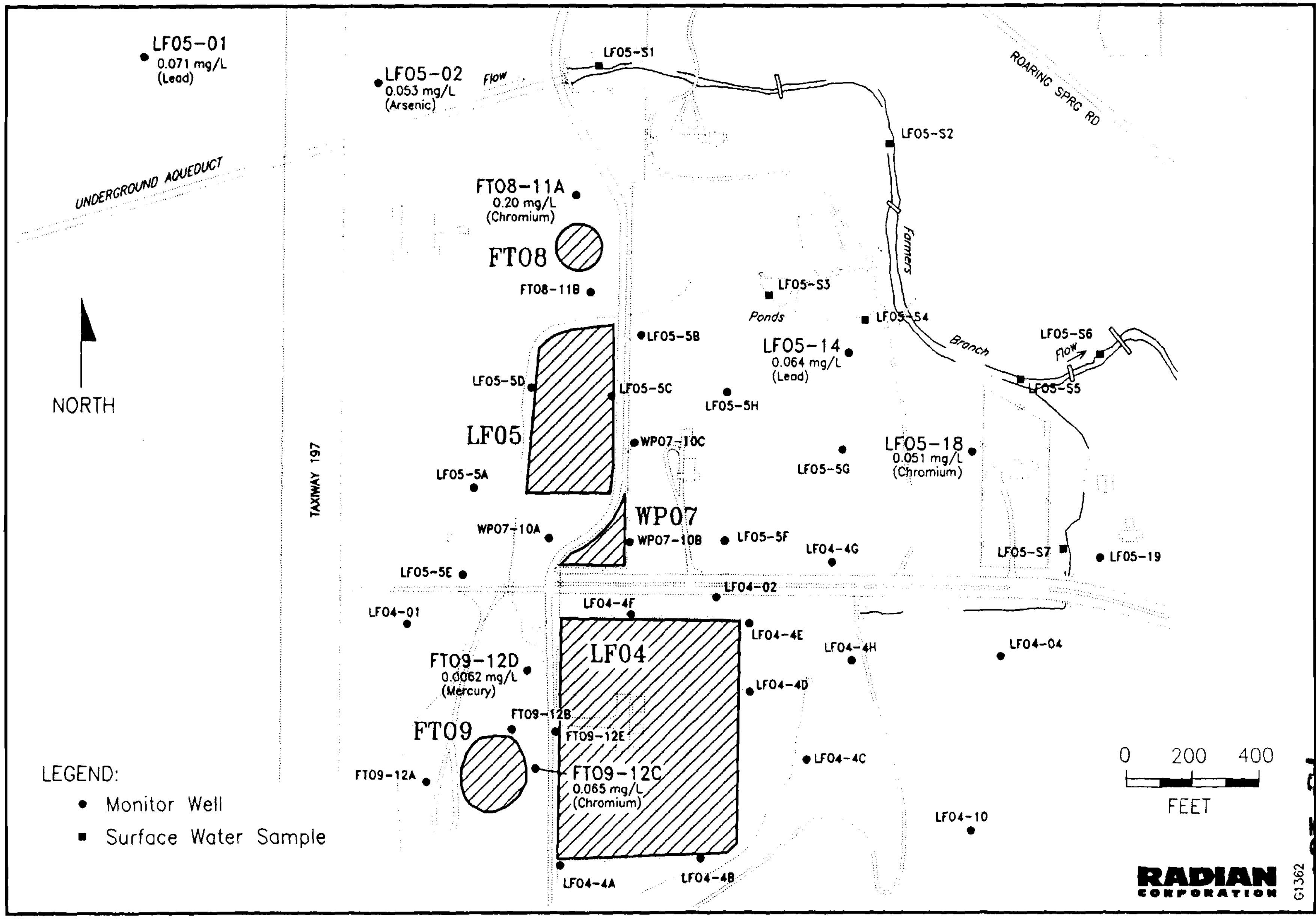

Figure 4-7. Location of Monitor Wells (BOLD Well Numbers) in Which EPA MCLs for Metals Were Exceeded, Flightline Area, Carswell AFB, Texas (Based on Spring, 1990 Water Sampling)

analyses are performed on unfiltered samples and as such may yield artificially elevated metal results, because fine suspended material in the unfiltered sample can break down during sample acidification releasing additional metals ions into the fluid medium. The dissolved metals analyses, performed on field-filtered samples, are considered more representative of the actual ground-water chemistry. In light of this, there is little evidence to support the existence of metal contamination in the Flightline Area at this time. In addition, the fact that a dissolved metal analysis was not performed during earlier sampling efforts, suggests that the previous data on metal contamination in the Flightline Area are inconclusive.

4.2.1.4 Ground-Water Quality Indicators

Analysis of numerous anions and cations was performed on samples from each monitor well in the Flightline Area to aid in the determination of ground-water quality. These included:

- Calcium;
- Magnesium;
- Potassium;
- Sodium;
- Chloride; and
- Sulfate.

In addition, total dissolved solids (TDS) were analyzed. Table 4-20 lists the averaged concentrations for each analyte by site (in the Flightline Area), as well as the overall average for the entire Flightline Area, weighted by site. Also, a range of concentrations for each analyte (except potassium) is provided which is considered 'typical' for Tarrant County (Texas Department of Water Resources, 1982). Concentrations for each analyte are in milligrams per liter.

At each site, calcium concentrations are elevated above the 'typical' range. In contrast, sodium concentrations fall uniformly below the

TABLE 4-20. SUMMARY OF GROUND-WATER QUALITY INDICATORS BY SITE, SPRING 1990, CARSWELL AFB, TEXAS, WITH TYPICAL RANGE FOR TARRANT COUNTY

Site/Locality	Averaged Concentrations, mg/L						
	Calcium	Magnesium	Potassium	Sodium	Chloride	Sulfate	Total Dissolved Solids
FT08	150	7.8	3.3	70	22	87	680
FT09	140	5.4	3.1	23.8	13	64.2	484
LF04	136.6	6.6	3.3	29	25.5	61.3	565
LF05	167.7	11.3	5.3	28.9	33.9	65.2	782
WP07	140	5.4	3.1	23.8	13	64.2	570
Flightline Area*	149.7	8.1	4.0	30.2	25.4	64.9	641.3
Tarrant County	1-114	0-11	--	141-670	14-650	21-579	381-1735

*Flightline Area averages were computed by the weighted probability method based upon the number of samples taken at each site.

given range. This is considered normal in ground water moving through lime-rich soils, such as those in the Flightline Area. All other ground-water quality indicator concentrations fall within the given range except the average chloride concentration in site FT09, which falls slightly below normal. Of significance is that a pronounced uniformity is evident between each of the sites in the Flightline Area, strongly suggesting an overall aquifer continuity, and further implying that the contaminants in the subsurface beneath each site are likely a part of the same contiguous plume.

4.2.2 Surface Water

Seven surface water samples were collected from the locations shown in Figure 4-8. Samples were collected from four locations along Farmers Branch, one from the unnamed tributary to Farmers Branch, and one each from the two small ponds near the golf course maintenance headquarters. Surface water sampling sites were selected both to characterize the nature and extent of surface water contamination and to determine the relationship, if any, between surface water and ground-water contamination. Surface water samples were also collected during the Phase II Stage 1 investigation (Radian, 1986).

4.2.2.1 Organic Contaminants

Table 4-21 summarizes the Spring, 1990 analytical results of organic constituents in surface water samples, with comparison to federal drinking water standards. Trichloroethene (TCE) was confirmed in all surface water samples, with federal MCLs being exceeded at five locations. Confirmed concentrations ranged from 1.8 μg/L at LF05-S3 to 1400 μg/L at LF05-S7. The elevated concentration at site LF05-S7 strongly suggests communication between the ground water and surface water at that location, as the concentration detected falls within the TCE isoconcentration contours generated for the ground-water analysis (Figure 4-2). Lower concentrations of TCE in samples collected from the upstream portion of Farmers Branch appear to be the result of an upgradient contaminant source. This is particularly evident at surface water sample location LF05-S1, which is located where the underground aqueduct emerges following transporting Farmers Branch water under the runway area of

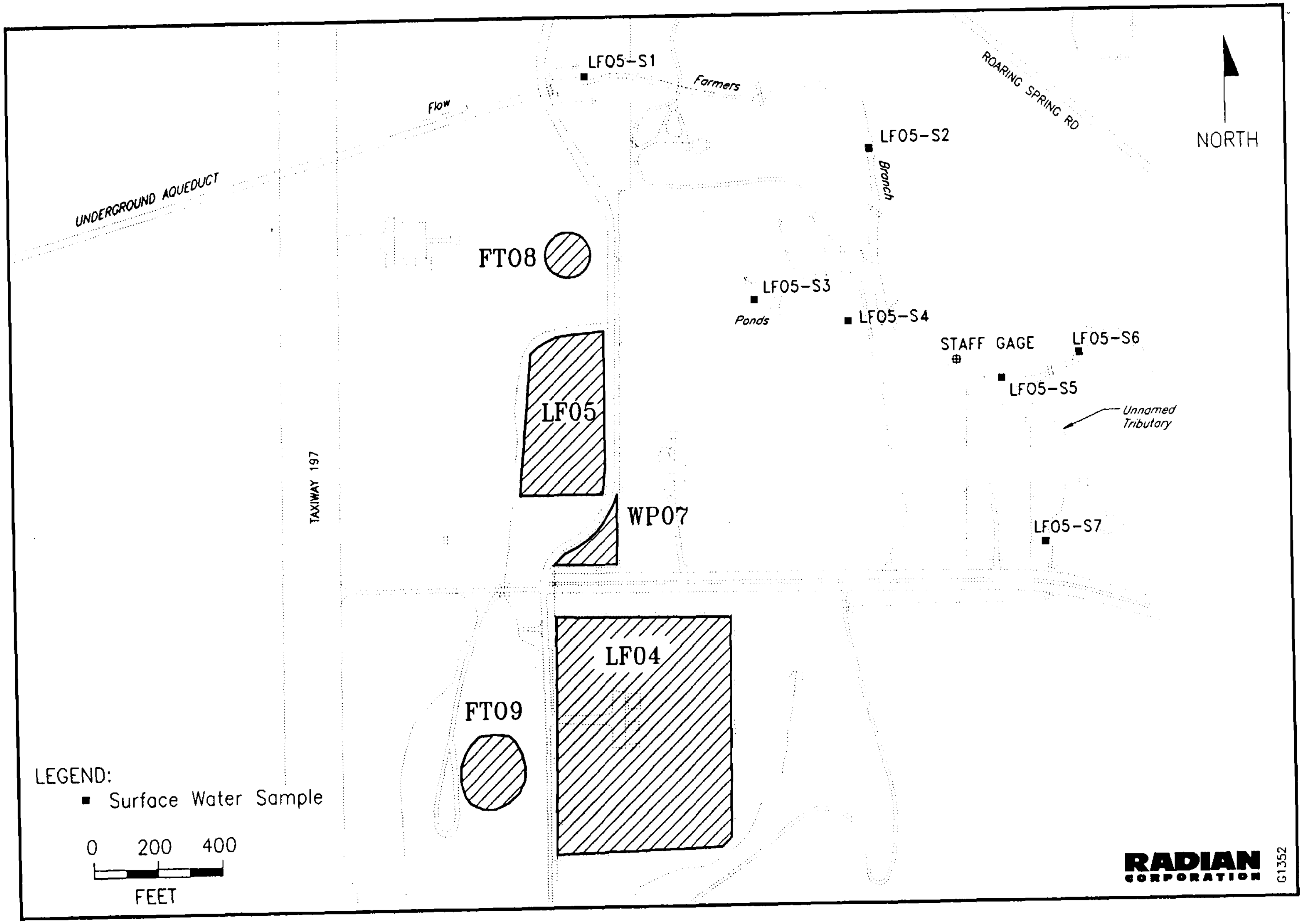

Figure 4-8. Location of Surface Water Sampling Points, Flightline Area, Carswell AFB, Texas (Spring, 1990)

TABLE 4-21. SUMMARY OF ORGANIC SURFACE WATER SAMPLING RESULTS, SPRING 1990, CARSWELL AFB, TEXAS

Analytical Parameter	EPA Standards* (µg/L)	Range of Detection Limits	Range of Concentrations of Constituents Detected	Total Number of Samples: Analyses for Constituent (No. of Locations)	Total Number of Samples: With Constituent Detected and Second Column Confirmation (No. of Locations)	Total Number of Samples: Exceeding EPA Standard (No. of Locations)
Purgeable Halocarbons (601) µg/L						
1,1,1-Trichloroethane	200 (M)	0.20-10.0	ND	8 (7)	0	0
1,1,2,2-Tetrachloroethane		0.15-7.5	ND	8 (7)	0	0
1,1,2-Trichloroethane		0.20-10.0	ND	8 (7)	0	0
1,1-Dichloroethane		0.50-25.0	ND	8 (7)	0	0
1,1-Dichlorethene	7 (M)	0.20-10.0	ND	8 (7)	0	0
1,2-Dichlorobenzene	600 (P)	0.50-25.0	ND	8 (7)	0	0
1,2-Dichloroethane	5 (M)	0.10-5.0	ND	8 (7)	0	0
1,2-Dichloropropane	5 (P)	0.10-5.0	ND	8 (7)	0	0
1,3-Dichlorobenzene		0.32-16.0	ND	8 (7)	0	0
1,4-Dichlorobenzene	75 (M)	0.24-12.0	ND	8 (7)	0	0
2-Chloroethylvinyl ether		0.50-25.0	ND	8 (7)	0	0
Bromodichloromethane		0.10-5.0	ND	8 (7)	0	0
Bromoform		0.50-25.0	ND	8 (7)	0	0
Bromomethane		1.2-59.0	ND	8 (7)	0	0
Carbon tetrachloride	5 (M)	0.12-6.0	ND	8 (7)	0	0
Chlorobenzene		0.25-13.0	ND	8 (7)	0	0
Chloroethane		0.52-26.0	ND	8 (7)	0	0
Chloroform		0.10-5.0	ND	8 (7)	0	0
Chloromethane		0.30-15.0	ND	8 (7)	0	0
Dibromochloromethane		0.20-10.0	ND	8 (7)	0	0
Methylene chloride		0.40-20.0	ND	8 (7)	0	0
Tetrachloroethene	5 (P)	0.10-5.0	ND	8 (7)	0	0
Trichloroethene	5 (M)	0.20-10.0	1.8-1400	8 (7)	8 (7)	6 (5)
Trichlorofluoromethane		0.20-10.0	ND	8 (7)	0	0
Vinyl chloride	2 (M)	0.20-10.0	0.56-3.7	8 (7)	2 (2)	1 (1)
cis-1,2-Dichloroethene	70 (P)	0.20-10.0	3.1-310.0	8 (7)	8 (7)	1 (1)
cis-1,3-Dichloropropene		0.20-10.0	ND	8 (7)	0	0
trans-1,2-Dichloroethene	100 (P)	0.20-10.0	0.46-0.66	8 (7)	2 (2)	0
trans-1,3-Dichloropropene		0.34-17.0	ND	8 (7)	0	0

*EPA standards are designated: M - Maximum Contaminant Level (MCL) and P - Proposed Maximum Contaminant Level (PMCL).

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Carswell AFB. Surface water at this location has yet to be influenced by any Carswell AFB waste sites, as it is transported through a concrete conduit from the vicinity of Air Force Plant 4. Any contamination in a sample from this location is due to upgradient sources in the direction of Air Force Plant 4 further upstream. Surface water sampled at this location contained a TCE concentration of 39 μg/L, which is above the MCL of 5 μg/L.

TCE was also confirmed in the Phase II Stage 1 investigation. Two rounds of samples were collected, with TCE being detected upgradient of Site LF04 in both rounds and immediately downgradient from Site LF05 in the second round (sampling points are shown on Figures 4-10 and 4-14 of the Stage 1 report (Radian, 1986)). No detected levels of TCE exceeded the MCL. No relationship was established between surface water and ground-water TCE concentrations during the Stage 1 study.

Vinyl chloride was the only other volatile organic compound detected in the surface water samples in excess of current MCLs during this investigation. Vinyl chloride was detected in two samples from the golf course ponds (LF05-S3 and LF05-S4). The MCL for vinyl chloride was exceeded in LF05-S3 where a concentration of 3.7 μg/L was detected. Vinyl chloride was detected at the two locations where the lowest levels of TCE was detected, possibly suggesting a parent/daughter relationship. Vinyl chloride was also detected in Stage 1 surface water samples.

The other volatile organic constituents confirmed at the surface water locations during the Spring 1990 sampling event were cis- and trans-1,2-dichloroethene (-DCE), which have MCLs. As in the case of the ground-water samples, the cis-1,2-DCE isomer was more prevalent than the trans-1,2-DCE isomer in surface water samples, with the cis- isomer occurring at each of the seven sample locations. Concentrations of cis-1,2-DCE ranged from 3.1 μg/L to 310 μg/L. Trans-1,2-DCE was confirmed in samples from two surface water locations, LF05-S2 and LF05-S3, with concentrations of 0.46 μg/L and 0.66 μg/L, respectively. As in the case of ground water, a direct correlation appears to exist between TCE and cis-1,2-DCE concentrations and the occurrence of each. Surface water sample LF05-S7 had the highest confirmed concentrations of both TCE (1400 μg/L) and cis-1,2-DCE (310 μg/L). The total-1,2-DCE concentration detected at this sample location also falls within the total-1,2-DCE isoconcentration contours generated for the ground-water analysis (Figure 4-6).

4.2.2.2 Inorganic Constituents

No metals were detected in any surface water samples in excess of MCLs. Barium was detected at each location, and lead was being detected at all locations except LF05-S4 and LF05-S7. Arsenic was detected at LF05-S3. The concentrations are not considered significant, since these metals were commonly detected in levels below MCLs in the ground-water samples, and metals are naturally occurring constituents.

Water quality indicators were analyzed in the surface water samples. This was done both to assess the surface water quality and to attempt to clarify surface water/ground-water relationships. Indicators analyzed included:

- Total Dissolved Solids;
- Calcium;
- Magnesium;
- Potassium;
- Sodium;
- Chloride; and
- Sulfate.

Table 4-22 provides the averaged results for each of the water quality indicators for the surface water samples, as well as a range of concentrations for each analyte (except potassium) which are considered 'typical' for Tarrant County. In addition, the weighted averaged results for the same indicators are provided for the ground-water samples collected in the Flightline Area.

TABLE 4-22. SUMMARY OF SURFACE WATER AND GROUND-WATER QUALITY INDICATORS, SPRING 1990, CARSWELL AFB, TEXAS, WITH TYPICAL RANGE FOR TARRANT COUNTY

	Averaged Concentrations, mg/L						
Locality	Calcium	Magnesium	Potassium	Sodium	Chloride	Sulfate	Total Dissolved Solids
Surface Water Samples	105.7	6.2	3	26.5	28.7	69.3	447
Flightline Area*	149.7	8.1	4.0	30.2	25.4	64.9	641.3
Tarrant County	1-114	0-11	--	141-670	14-650	21-579	381-1735

*Flightline Area averages were computed by the weighted probability method based upon the number of samples taken at each site.

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Only sodium occurs outside the range provided for the indicators analyzed, being considerably below what would be considered a 'normal' concentration. This was also the case in the ground-water samples. The similarity between the averaged surface water results and the averaged ground-water results strongly supports the interrelationship of the two water systems. This interrelationship has previously been discussed, and data generated at the site shows the unnamed tributary to Farmers Branch to be an influent stream in the Flightline Area. Only calcium differs slightly, with an averaged concentration in the ground water of approximately 45 mg/L greater than that of the surface water. This phenomenon is probably due to minor differences in the alkalinity of the two systems.

4.3 Summary of Findings

The main findings of the Flightline Area investigation with respect to the nature and extent of ground-water contamination are:

- Concentrations of TCE and vinyl chloride exceed MCLs in Upper Zone monitor wells in the Flightline Area.

- Multiple sources, including Sites LF04, LF05, WP07, FT09, and Air Force Plant 4, have been postulated for the various organic contaminant plumes which occur in the Flightline Area.

- Some downgradient migration of the plume apex and a decrease in total TCE concentration may have occurred since the monitor well network was previously sampled in 1988. However, continued monitoring is necessary to verify this possible trend, which could also be related by variability inherent in field and laboratory procedures or seasonal conditions.

- The extreme western limit of the Flightline Area TCE plume is as yet still undefined, but high levels of TCE and other contaminants detected in wells far upgradient of any known source areas or Carswell AFB strongly support the existence of additional upgradient source(s), potentially associated with documented TCE contamination in Upper Zone ground water beneath Air Force Plant 4.

- The extreme eastern (downgradient) limit of the TCE plume in the Upper Zone is also undefined.

- The vertical extent of contamination in the Flightline Area appears to correspond to the upper surface of the underlying Goodland/Walnut aquitard based on limited analytical results. Previous sampling of the two Paluxy Aquifer monitor wells did not detect any contamination.

- It is unlikely that any significant metals contamination exists in the Upper Zone Aquifer of the Flightline Area, as no dissolved metals concentrations exceeded MCLs.

- Both TCE and vinyl chloride were detected in excess of MCLs in surface water samples.

- Based upon the similarity between ground-water and surface water TCE concentrations, the unnamed tributary to Farmers Branch appears to be a zone of ground-water discharge.

- A pronounced similarity between surface water and ground-water quality indicators (and other analytes) supports the existence of zones of communication between the two water systems.

- In addition to contaminant contributions from unidentified upgradient source(s), the Flightline Area sites appear to be releasing some additional volatile organic compounds (mainly TCE, vinyl chloride, and 1,2-DCE) to the larger contaminant plume.

- Further investigation is required in the area between the Flightline Area sites and the upgradient source(s) to determine the relative contributions of each to Upper Zone groundwater contamination in the Flightline Area.

5.0 CONTAMINANT FATE AND TRANSPORT

The purpose of this section is to define the interrelationships between the various contaminant plumes which exist in shallow (Upper Zone) ground water in the Flightline Area, and to discuss their migration and persistence. The transport and fate of contaminants in the Flightline Area and the potential for off-site or off-base migration is a function of the physical hydrogeologic conditions and the plume interrelationship.

Volatile organic contaminants found in both the ground water and the surface water in the Flightline Area are the only hazardous waste constituents having a potential for off-site or off-base migration at levels of concern. No dissolved concentrations of inorganic constituents, specifically metals, were identified in the ground water at levels exceeding federal primary drinking water standards. Risk assessments were performed earlier during the Phase II Stage 2 investigation, however these focused principally on airborne hazards.

The ground-water contaminant plume in the Flightline Area is best described in terms of trichloroethene (TCE). ~~As stated in Section 4,~~ TCE is the principal contaminant at the site, with detected concentrations of up to 4400 μg/L and exceeding EPA's MCL (5 μg/L) in 27 wells. Other contaminants which are less widely distributed or occur in lower concentrations within the main Flightline Area plume include vinyl chloride, cis- and trans-1,2-dichloroethene, tetrachloroethene, and several other volatile organic halocarbon compounds.

5.1 Contaminant Persistence and Transformation

5.1.1 Background and Theory

The fate and persistence of the volatile organic contaminant plume in the Flightline Area is controlled by processes such as convection, contaminant adsorption and desorption on soil matrices, diffusion and dispersion, chemical and biological degradation, and volatilization and subsequent resorption. Additionally, the nature of the contributing source(s), with regard to initial concentration and availability of contaminants, affects both fate and transport.

Diffusion and dispersion are chemical and mechanical processes whereby a contaminant tends to spread from the expected direction of transport governed by ground-water flow patterns. Diffusion depends on concentration gradients, and causes compounds to spread in the direction of lower concentrations. Dispersion is a function of mechanical transport, where physical mixing of the fluid media due to drag effects and pore channel tortuosity tend to cause some lateral solute spreading. Both of these phenomena contribute to dilution of specific contaminants within the body of the plume, but also result in the enlargement of the plume. Thus, these phenomena are factors in contaminant persistence and apparent retardation during transport.

Adsorption and desorption of a solute can be significant factors affecting the fate and transport of many types of contaminants. Compounds that are readily adsorbed onto grains of the aquifer material, and not readily desorbed are removed from the ground-water system and are not available for transport. Chemical partitioning by sorption can reduce effective transport by up to 100 percent. However, TCE is classified as a 'mobile' solute based upon its relatively low affinity to adhere to particles in the solid matrix. This classification is based on mobility, the value K_d, from the equation:

$$K_d = \frac{a_s}{a_w}$$

where: K_d - the soil-water distribution coefficient;
a_s - the activity of the solute in the soil matrix; and
a_w = the activity of the solute in the aqueous phase.

Mobility classes range from 'immobile' to 'very mobile', with TCE being in the second most mobile class out of five possible classes. In terms of solute transport, TCE has a higher activity in the aqueous phase, and hence will tend to both adsorb and desorb from soil grains with relative uniformity. Consequently TCE (and related daughter products) have a capacity for transport which is only slightly retarded with respect to that due to the flow of ground water.

Mobility (K_d) is also a function of the concentrations of available solute, as the chemical activity of a solute will fluctuate based upon the chemical saturation of the parent media. One method of estimating K_d is based on site specific knowledge of TCE concentrations in the solid and aqueous phases. For the purpose of this report, TCE will be simply treated as a mobile solute, with adsorption and desorption being a factor in transport retardation.

As in the case of adsorption and desorption, TCE and other organic compounds may volatilize during transport and then be resorbed back into the aqueous phase. Chlorinated solvents are volatile compounds. Resorption of compounds following volatilization is based upon their ability to be adsorbed onto soil grains in the unsaturated zone and then be resorbed back into the ground water during periods of ground-water level fluctuation. Some compounds, such as 1,2-DCE and vinyl chloride, have low sorption coefficients, and consequently might be permanently removed from the ground-water system following volatilization. Because TCE is considered volatile and sorptive, some portion of the volatilized compound could re-enter the ground-water system during potentiometric (water level) rises. However, since the Upper Zone water table in the Flightline Area has not fluctuated significantly since 1985 when potentiometric surveys began, volatilization may possibly cause permanent removal of organic compounds from the ground water and therefore be a contributing factor in transport retardation. The degree of significance of this phenomenon is not known at the present time.

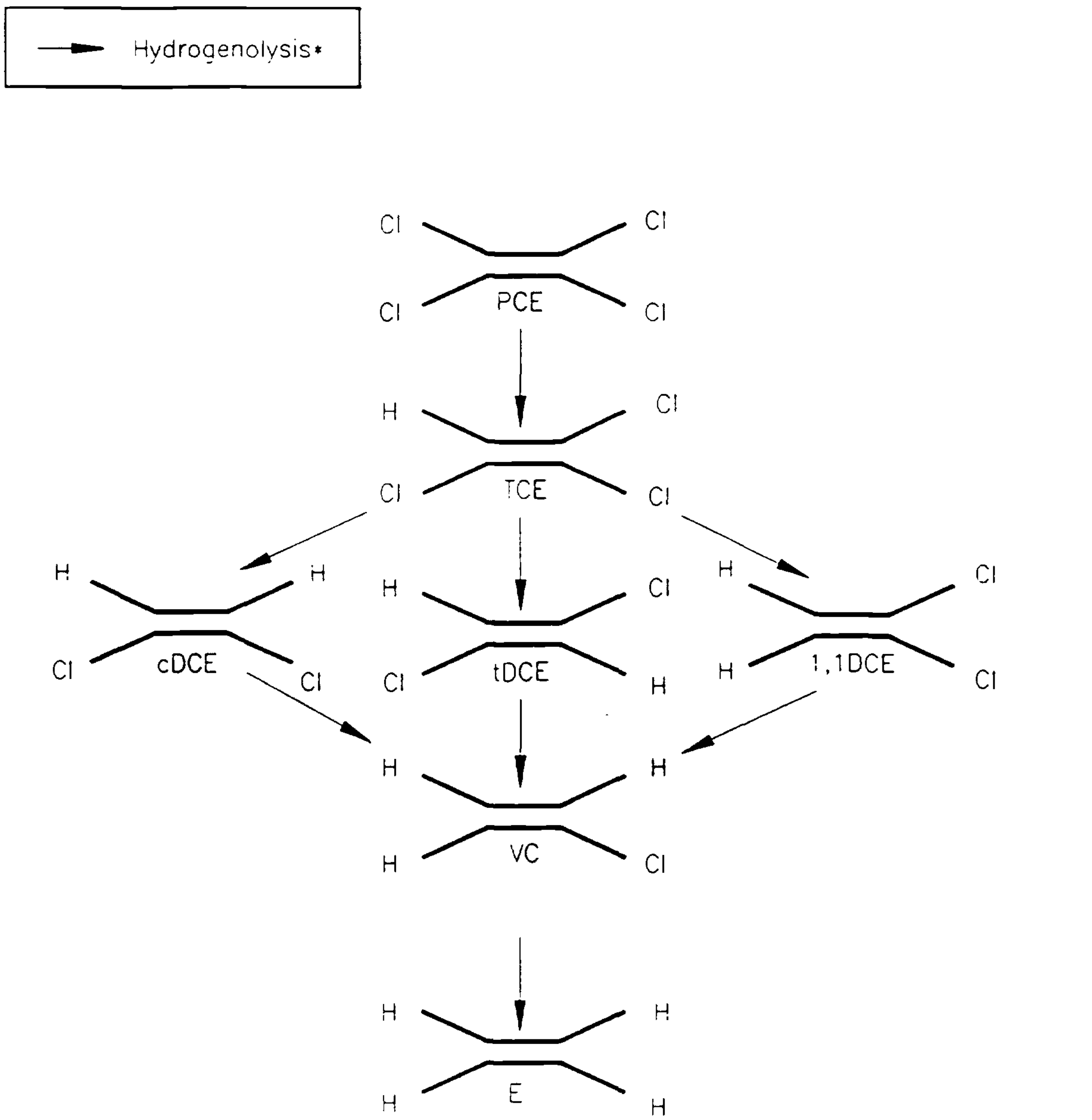
Chemical and biological degradation of the organic compounds in the Upper Zone ground water are potentially important factors in transport retardation in the Flightline Area. Tetrachloroethene (PCE), trichloroethene (TCE), cis- and trans-1,2-dichloroethene and vinyl chloride are all related by the chemical process of hydrogenolysis. From this reaction, PCE is broken down into a series of daughter products, ultimately yielding carbon dioxide and water. This process is very common in nature, and may be biologically driven, as a form of biodegradation.

Figure 5-1 provides a summary of the three chemical and biological transformation pathways for the four principal organic contaminants in the Flightline Area. It is noteworthy that the half-lives for these pathways vary from tens of days to two to three years, and the pathway to cis-1,2-DCE is generally favored. Since TCE and PCE formerly were both widely used industrial solvents, some amount of TCE is probably from a primary source. It is doubtful that the sole source of TCE detected in the Flightline Area is from the breakdown of PCE. However, with the limited amount of PCE detected, either a significant portion of the original concentration of this solvent has broken down into TCE or related daughter products, or the original volume of PCE was much lower than TCE.

5.1.2 Flightline Area (Golf Course) Data

Figures 5-2, 5-3 and 5-4 present the isoconcentration maps generated for TCE, 1,2-DCE and vinyl chloride, respectively. This discussion of fate and transport of the ground-water contaminant plume does not consider the data north of the Farmers Branch underground aqueduct. There is insufficient lithologic and hydrogeologic data from the area between monitor well LF05-01 (to the north) and monitor wells LF05-5A and LF05-5E (to the south) to make a plausible interpretation of contaminant relationship between the areas.

Based on the previous discussion and the knowledge that 1,2-DCE and vinyl chloride are not known to be used at the base, it is reasoned that the presence of 1,2-DCE and vinyl chloride are the result of the chemical and biological breakdown of TCE. By comparing the zones of highest concentrations in these three plumes, some scenarios can be suggested regarding the timing and continuity of the contaminant sources. Reviewing the figures:



PCE – tetrachloroethene
TCE – trichloroethene
cDCE – cis-1,2-dichloroethene
tDCE – trans-1,2-dichloroethene
1,1DCE – 1,1-dichloroethene
VC – vinyl chloride
E – ethene

* A reduction reaction in which a carbon-halogen bond is broken and hydrogen replaces the halogen substituent.

Source: Vogel, Criddle and McCarty, 1987

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Figure 5-1. Potential Degradation Products and Reaction Mechanisms for Reduction of Chlorinated Ethanes and Ethylenes

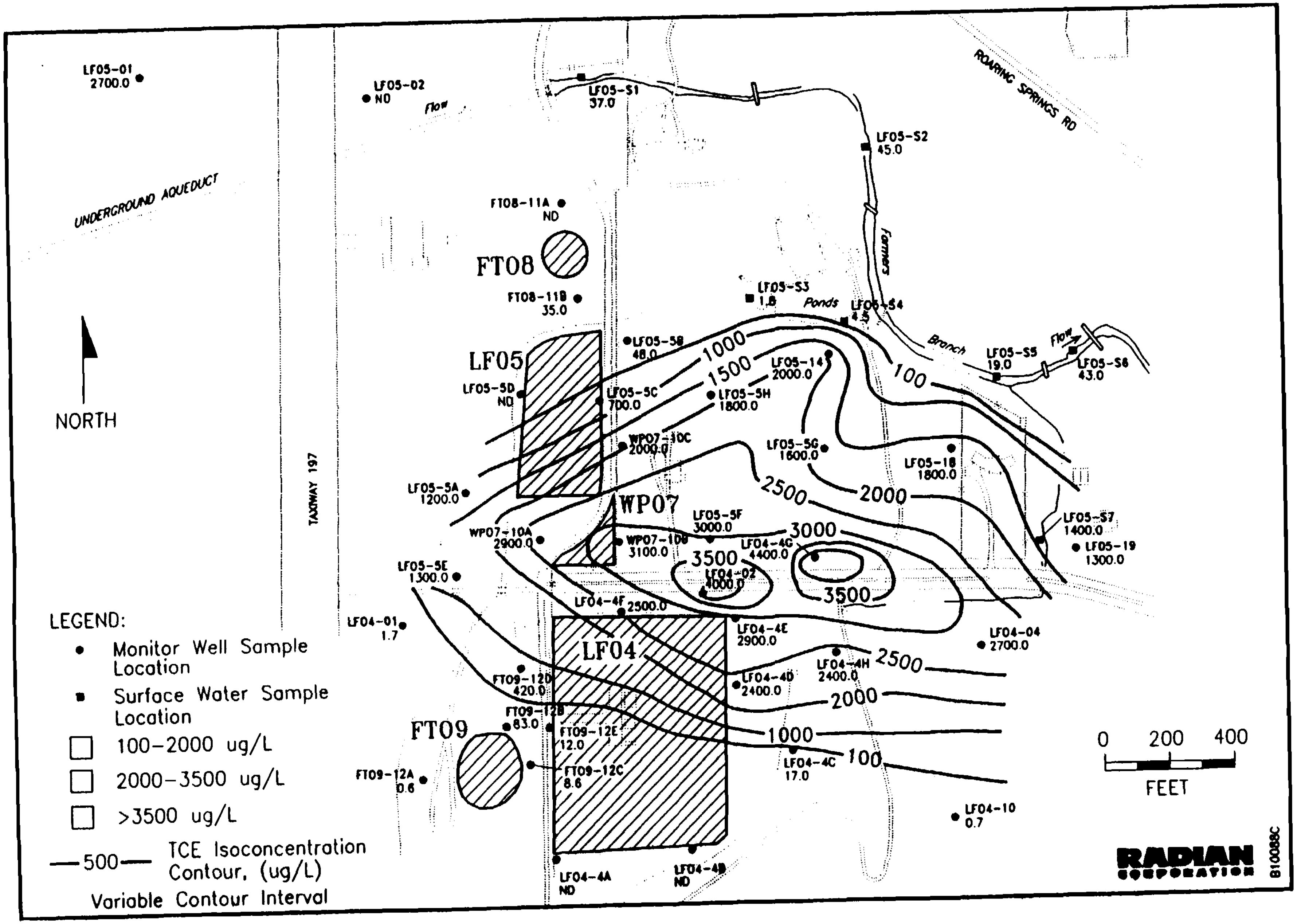

Figure 5-2. TCE Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas (Spring, 1990)
Note: Figure will be colored in Final Report

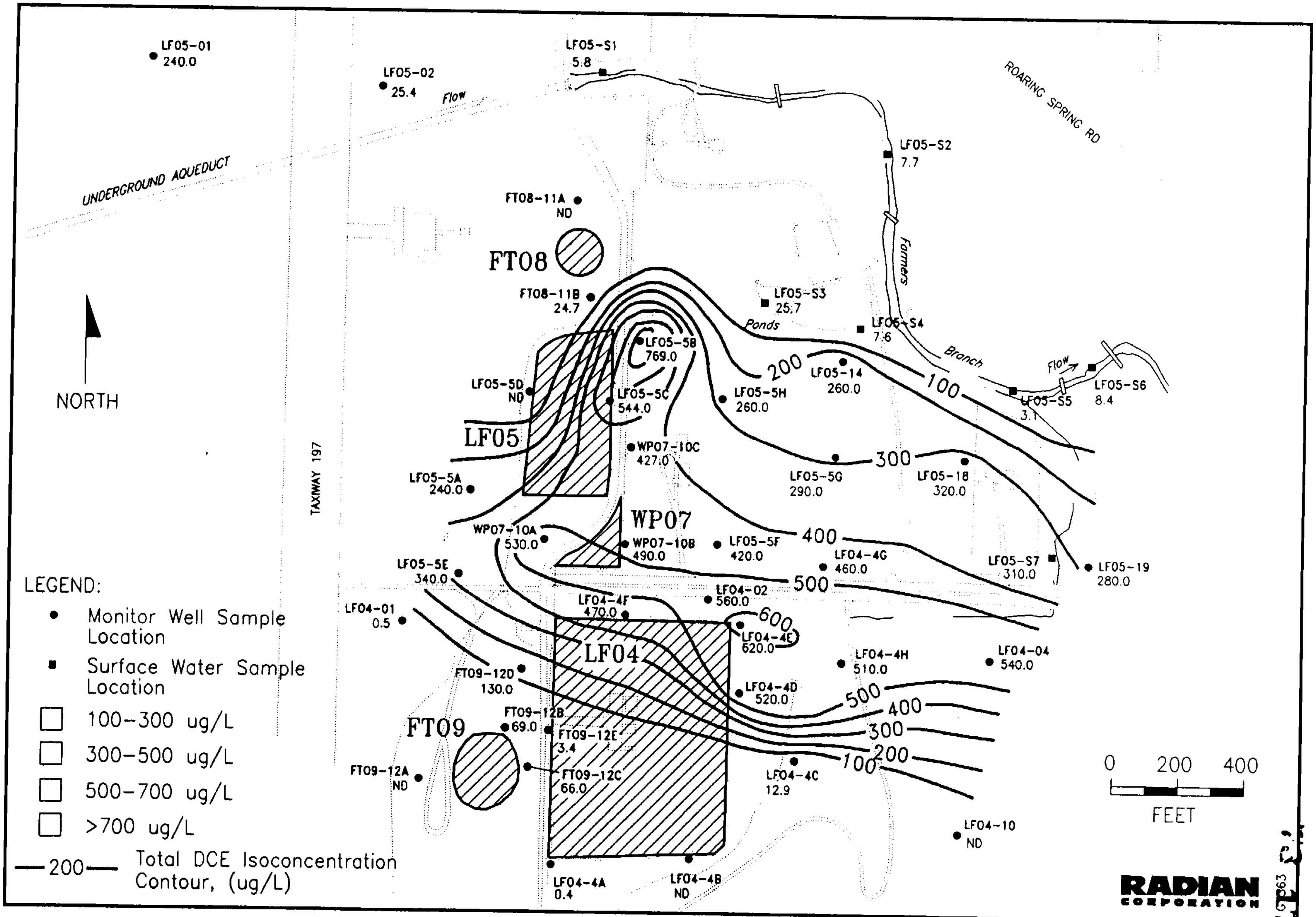

Figure 5-3. Total-1,2-DCE Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas (Spring, 1990)
Note: Figure will be colored in Final Report

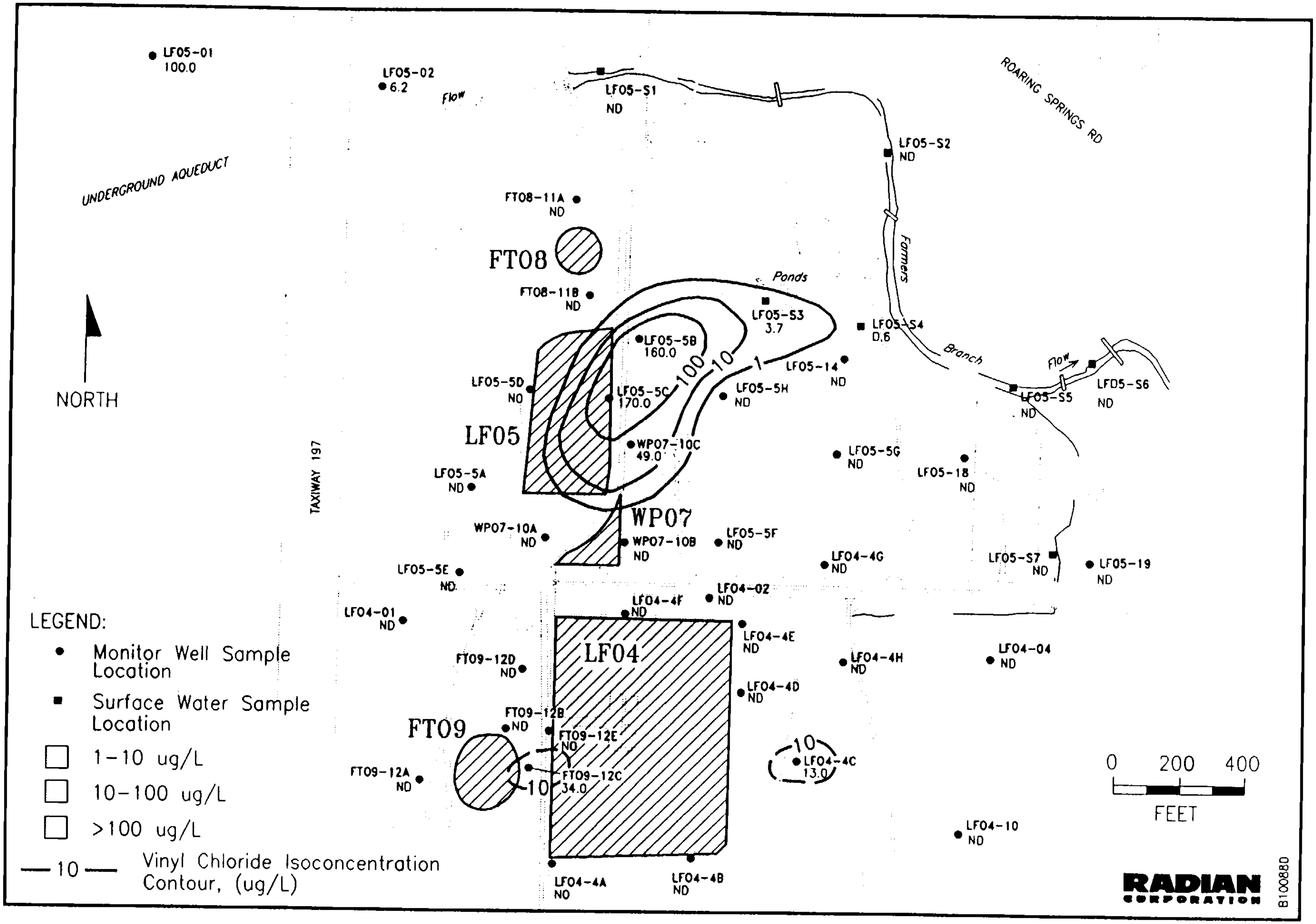

Figure 5-4. Vinyl Chloride Isoconcentration Contour Map, Flightline Area, Carswell AFB, Texas (Spring, 1990)
Note: Figure will be colored in Final Report

- During the Spring 1990 ground-water sampling, the apex of the TCE plume (Figure 5-2) was centered along White Settlement Road, roughly hydraulically downgradient from Landfill 4 (Site LF04);

- A small irregular area of elevated TCE concentrations (Figure 5-2) is present around monitor well LF05-14, downgradient from Landfill 5 (Site LF05);

- The 1,2-DCE (Figure 5-3) plume has highest concentrations immediately downgradient from Sites LF05 and LF04, with gradually decreasing concentrations downgradient of both landfills; and

- Finally, vinyl chloride (Figure 5-4) is present almost exclusively hydraulically downgradient of Site LF05.

If 1,2-DCE and vinyl chloride concentrations detected in the ground water are directly the result of TCE degradation, then a comparison of the locations and concentration distributions within the plumes suggests an earlier introduction of TCE from Site LF05 into shallow ground water, with significant degradation to 1,2-DCE and vinyl chloride having occurred, and a later release from Site LF04, where time has allowed only degradation to 1,2-DCE to occur. Furthermore, the overall release of contaminants from Site LF04 may have decreased somewhat with time, as concentrations of TCE immediately downgradient from Site LF04 were lower than in the previous sampling in April 1988.

The fact that cis-1,2-DCE is favored in the chemical breakdown of TCE supports the hypothesis that all of the 1,2-DCE present in the Flightline Area results from TCE degradation. As stated earlier, cis-1,2-DCE is present in concentrations far exceeding trans-1,2-DCE, and the compound was detected in five times as many wells. This would be expected if the two compounds were daughter products of TCE, as the breakdown pathways of TCE to trans-1,2-DCE or 1,1-DCE are considered minor. However, all of the interpretations in this section are speculative. Review of the historical ground-water chemical data from the Flightline Area indicates considerable variability in concentrations of volatile organic compounds over short periods (i.e., between monthly sampling rounds). These fluctuations are unlikely to be related to longer-term degradation patterns.

5.2 Contaminant Migration Pathways

Ground water and surface water at the Flightline Area appear to be in hydraulic communication, based on results of synoptic water level measurements, and supported by chemical analyses from surface-water and ground-water samples. The water quality indicator compounds in each system were similar, and the detected contaminants occurred in similar proportions. Ground-water contaminants TCE and 1,2-DCE were also detected in each surface-water sample. In addition, as discussed in Section 4, the concentrations of TCE and 1,2-DCE detected at surface-water sampling points were consistent with contaminant concentrations at nearby ground water sampling locations. These correlations support hydraulic connection between ground water and surface-water systems. Furthermore it is apparent that the tributary to Farmers Branch is a point of ground-water discharge which ultimately contributes contaminated water to Farmers Branch. To simplify the discussion of contaminant transport, the migration of the contaminant plume will be described individually in terms of the ground-water and surface-water systems.

5.2.1 Transport in Ground Water

Comparison of Figures 5-2 (Spring 1990) and 5-5 (April 1988) showing TCE concentrations in ground water suggests that some migration of the TCE plume has occurred. Recognizing that the interpreted isoconcentration contours can partially reflect sampling and analytical variabilities, the apex of the plume, once centered on monitor well WP07-10B, is now centered between monitor wells LF04-4G and LF04-02. If this change is attributed to advection, it represents a migration distance of dissolved TCE of approximately 550 feet.

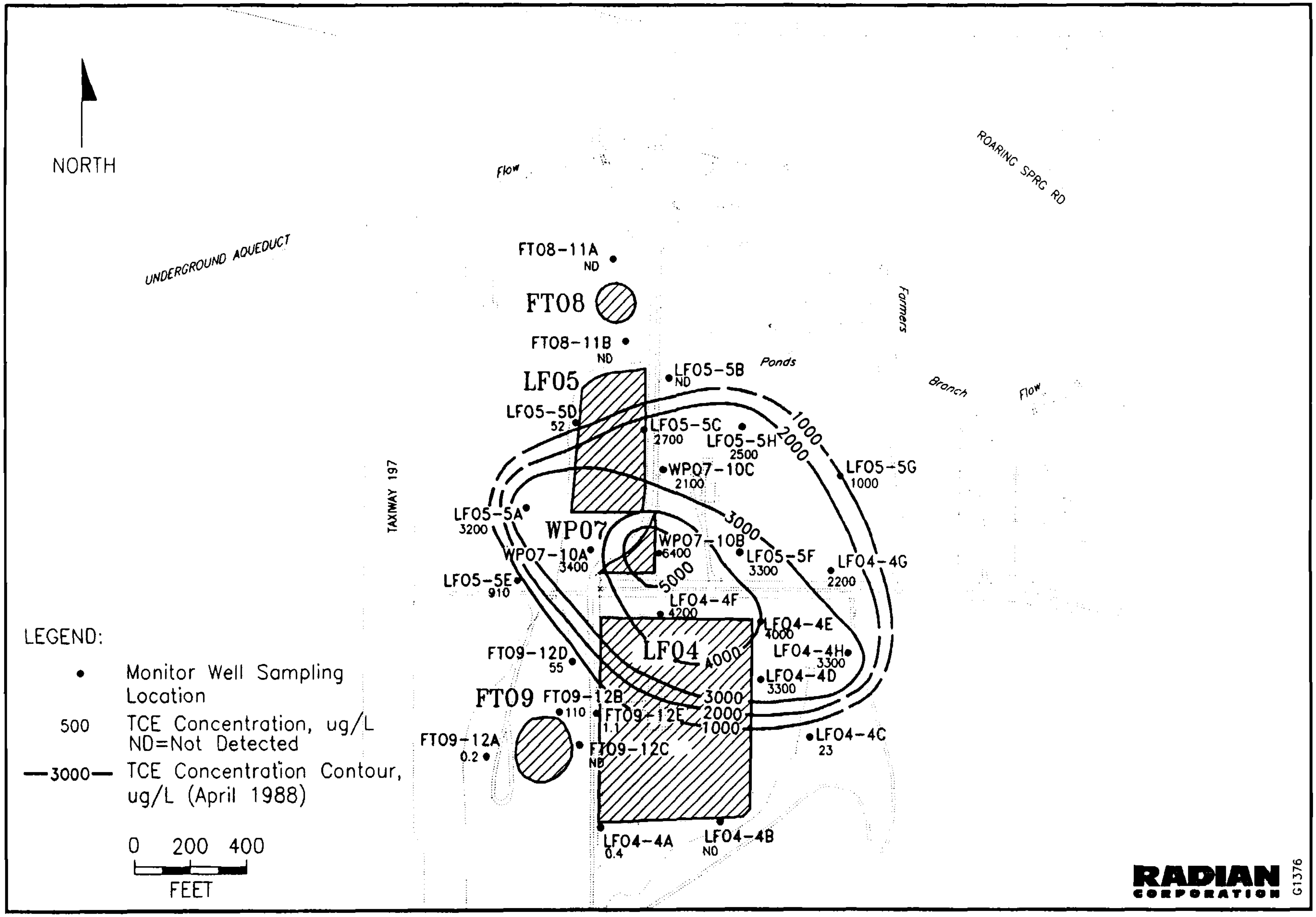

Figure 5-5. Isoconcentration Contour Map of TCE Concentrations from April 1988 Upper Zone Ground-Water Sampling, Flightline Area, Carswell AFB, Texas

Data generated from Upper Zone Aquifer pump testing, performed in June 1990, and water-level data suggest the average ground-water flow rate in the Upper Zone is approximately 9 feet per day. This is based on a hydraulic conductivity of 785 feet/day and an hydraulic gradient of 0.0035. Since the hydraulic conductivity derived from aquifer testing falls in the suggested range for clean sands to gravels (Freeze and Cherry, 1979), a porosity of 30% was assumed. The estimate for the average ground-water flow velocity is derived from a simplification of Darcy's Law:

$$\bar{v} = \frac{Ki}{\phi}$$

where: $\bar{v}$ = average ground-water flow velocity

K = hydraulic conductivity of Upper Zone Aquifer (average 2.8×10^{-1} cm/sec or 785 feet/day),

i = hydraulic gradient (0.0035) in the Upper Zone; and

ϕ = estimated porosity of the Upper Zone deposits (0.30).

By comparing this flow velocity with the apparent change in the position of the TCE plume after slightly more than two years, the plume appears to be migrating at a rate of less than 1 foot per year, or an order of magnitude slower than ground-water flow. This is not unusual based upon the physical, chemical and biological factors which affect the solute mobility with respect to ground water, as previously discussed in Section 5.1.

The main contaminant plume appears to be migrating in a direction which is generally consistent with the direction of ground-water flow. Figure 5-6 shows a potentiometric surface map generated from the June 1990 water level survey, with the corresponding ground-water flow directions indicated. The dominant direction of migration closely follows the orientation of the thickest accumulation of sand and gravel in the Flightline Area (Figure 5-7). A comparison of the sand and gravel isopach map with the recent TCE plume map (Figure 5-2) clearly indicates that plume migration may be preferentially influenced by the increased porosity and hydraulic conductivity of the sand and gravel interval.

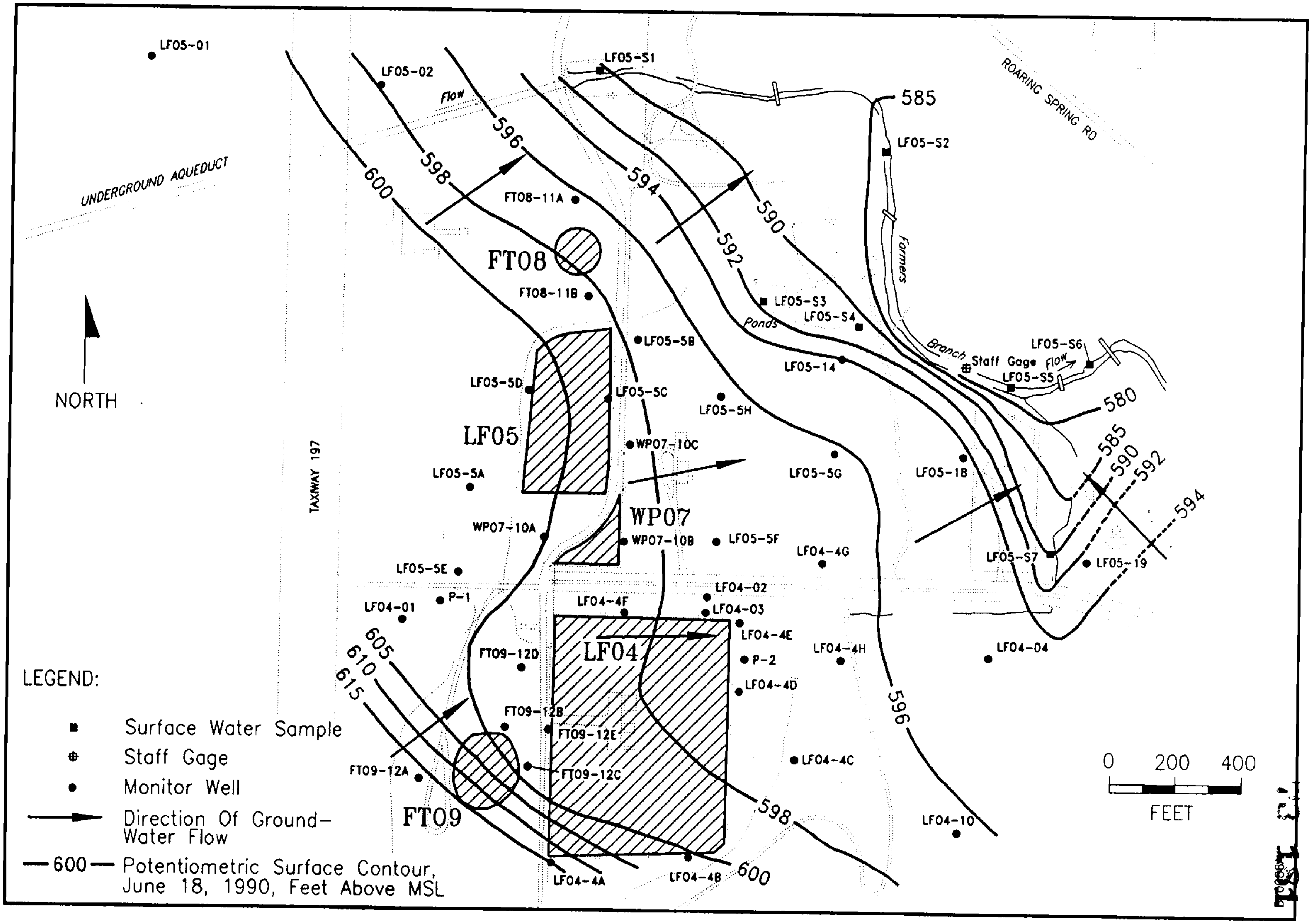

Figure 5-6. Upper Zone Aquifer Potentiometric Surface Map (June, 1990), Flightline Area, Carswell AFB, Texas

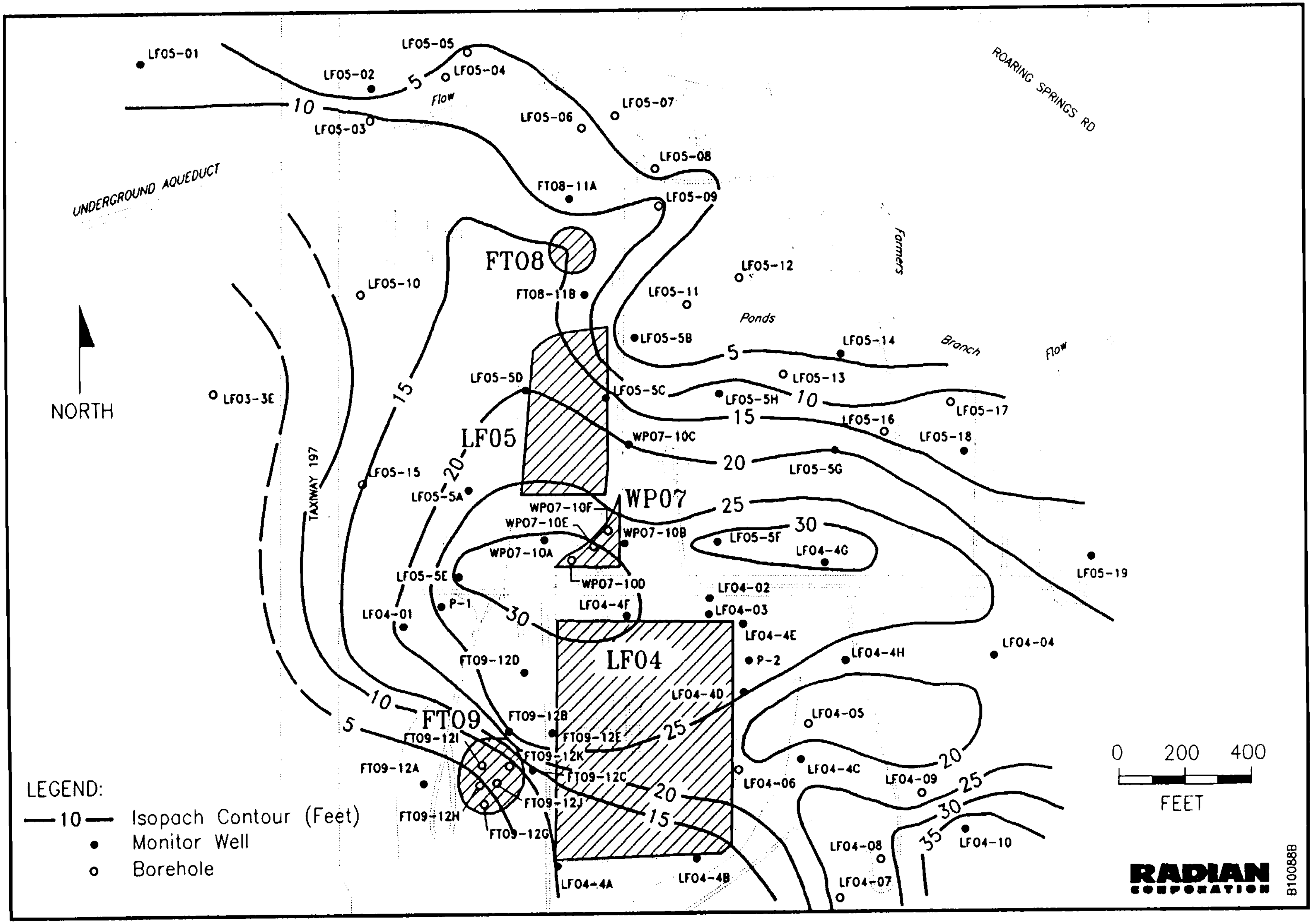

Figure 5-7. Sand and Gravel Isopach Map, Flightline Area, Carswell AFB, Texas

The direction of plume migration appears to be roughly parallel to White Settlement Road. The maximum extent of the plume in that direction is unknown, as samples from the two most easterly monitoring wells, LF04-04 and LF05-19 had detected levels of 2700 and 1300 μg/L TCE, respectively, in the Spring 1990 sampling event. However, given historical observations and at the estimated rate of contaminant transport, the apex of the contaminant plume would not be expected to migrate beyond the general locations of LF04-04 and LF05-19 within the next several years.

It is along this vector of migration that the plume most directly intersects the unnamed tributary to Farmers Branch. Both TCE and 1,2-DCE were found in high concentrations in surface-water sample LF05-S7 (collected from the small tributary (Figure 5-2)). At this locality, contaminated ground water appears to discharge directly into the surface water, which in turn flows into Farmers Branch. Because upstream flow in this small tributary intermittently disappears into the subsurface (from the southeast corner of LF04 to just upstream of LF05-S7), it is likely that the water at the sampled location is almost entirely the result of ground-water discharge. However, as evident from Figure 5-2, the tributary is not a ground-water flow boundary and thus all ground-water contamination in the vicinity of the small tributary is not 'captured' or diverted as surface-water flow. This conclusion is also supported by the finding of elevated concentrations of TCE and 1,2-DCE in wells hydraulically downgradient of the tributary. This is most evident on the south side of White Settlement Road, where TCE was detected at 2700 μg/L in monitor well LF04-04, south (downgradient) of the small tributary. Also, test well LF05-19 is located east of the unnamed tributary and has a TCE concentration of 1300 μg/L. Migration of a portion of the contaminants continues in an east-southeasterly direction past the location of LF04-04.

The more northerly component of the TCE plume migration, which parallels the direction of ground-water flow, is toward Farmers Branch. Farmers Branch was sampled at four locations in the Spring 1990 sampling event. While the dominant ground-water flow is in the direction of Farmers Branch, the main contaminant plume has not indicated a strong preferential migration in that direction. TCE concentrations of 1.8 and 4.5 μg/L, found in surface-water samples collected in two small ponds located immediately north of monitor well LF05-14, appear to approximate the northerly extent of the TCE plume. Any potential contaminant migration to the east of these ponds would be intercepted by Farmers Branch. Since no samples have been collected on the opposite side (northern) of Farmers Branch, it is uncertain whether the ground water on that side of the stream is contaminated. Contamination in Farmers Branch and the unnamed tributary to Farmers Branch is discussed in Section 5.2.2, below.

TCE has not been encountered as a dense non-aqueous phase liquid (DNAPL) in monitor wells installed in the Flightline Area, however, if DNAPL does exist, it would tend to sink due to the difference in specific gravity between TCE and water. Figure 5-8 depicts a structural contour map drawn on the top of the Goodland/Walnut Formation, which is the aquitard beneath the Upper Zone and considered to be the limit of vertical contamination. It is probable that migration of any DNAPL would be influenced by the configuration of the top of the aquitard. The solubility of TCE in water is 1100 mg/L, and based on the analyses received from the various sampling efforts, concentrations sufficient to warrant the presence of TCE as a DNAPL are not expected in the Flightline Area. While TCE may have been released in a pure phase from one of the source sites, immediate and extensive dilution occurs as the leachate enters the ground water, as reflected in the TCE concentrations detected in downgradient wells. Based on the concentrations of contaminants detected in the Flightline Area contaminant plume, the density of the water would not be expected to be much greater than that of fresh water. However, preferential migration of the contaminant plume through the thickest Upper Zone sand and gravel deposits and above the most eroded surfaces of the underlying aquitard is occurring in the Flightline Area.

5.2.2 Transport in Surface Water

Surface-water contamination in the Flightline Area is affected by both the extent and migration of the ground-water plume, and by the variations in the discharge and velocity of the two principal surface-water bodies

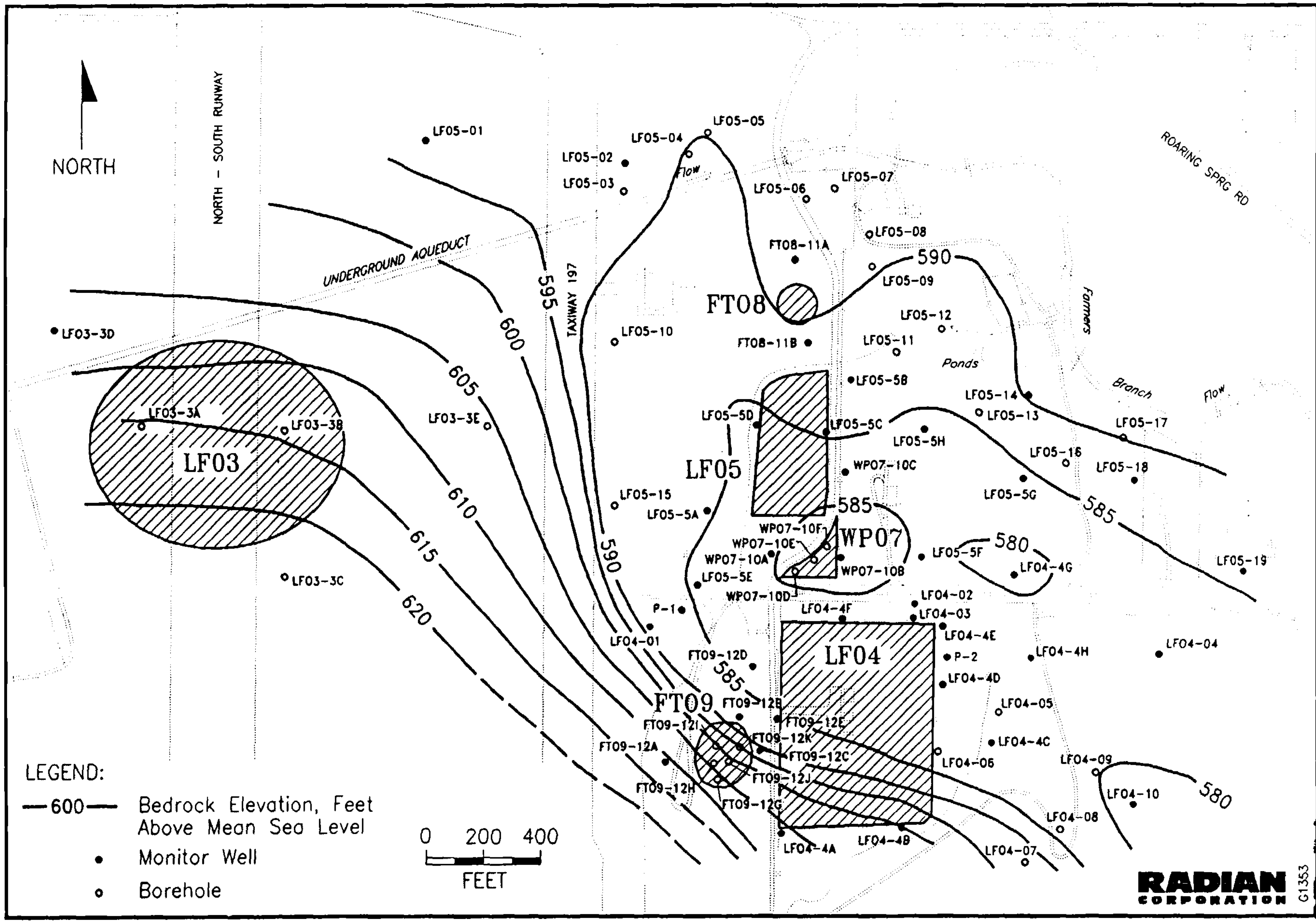

Figure 5-8. Elevation (MSL) of the Top of the Goodland/Walnut Formation, Flightline Area, Carswell AFB, Texas

occurring in the area. Farmers Branch, which ultimately flows off-site, had variable concentrations of TCE and 1,2-DCE based on the sample location. In addition, Farmers Branch is fed by the small unnamed tributary draining the southern portion of the study area from which the most highly contaminated surface-water samples were collected. As a consequence, surface-water contaminant transport will be considered exclusively in terms of Farmers Branch. For the purpose of this discussion, Farmers Branch will be divided into three reaches, each with a different contaminant input and potential for contaminant migration.

Figure 5-9 shows the location of the surface-water sampling sites and Farmers Branch divided into three reaches to facilitate discussion of contaminant fate and transport processes occurring in each. The first reach of Farmers Branch includes the upstream portion from the end of the concrete underground aqueduct to the waterfall adjacent to the golf course ponds. This section of Farmers Branch is not influenced by the main TCE plume, as the golf course ponds are located approximately at the northern edge of the plume. TCE was detected, however, in the two samples collected in this reach. The TCE in these samples is believed to be the result of the upgradient source previously mentioned in this report. While the TCE detected in this portion of Farmers Branch is significantly above federal primary drinking water standards, it is probable that contamination observed in this reach does not contribute greatly to the overall observed downstream concentration of TCE. It is probable that a large percentage of all volatile organic contaminants (including TCE and 1,2-DCE) are stripped from the stream by volatilization as the stream crosses the waterfall which separates the first reach from the second reach.

The second designated reach of Farmers Branch includes that portion which is downstream of the waterfall and upstream of the intersection of Farmers Branch and the small tributary. In this reach, the main TCE plume appears to intersect the stream, and both TCE and 1,2-DCE contamination was detected in sample LF05-S5. However, even with continued migration of the main TCE plume in the direction of Farmers Branch, the concentration detected in this segment of the stream is not expected to increase significantly, and hence is not expected to be a major contributor to downstream contamination.

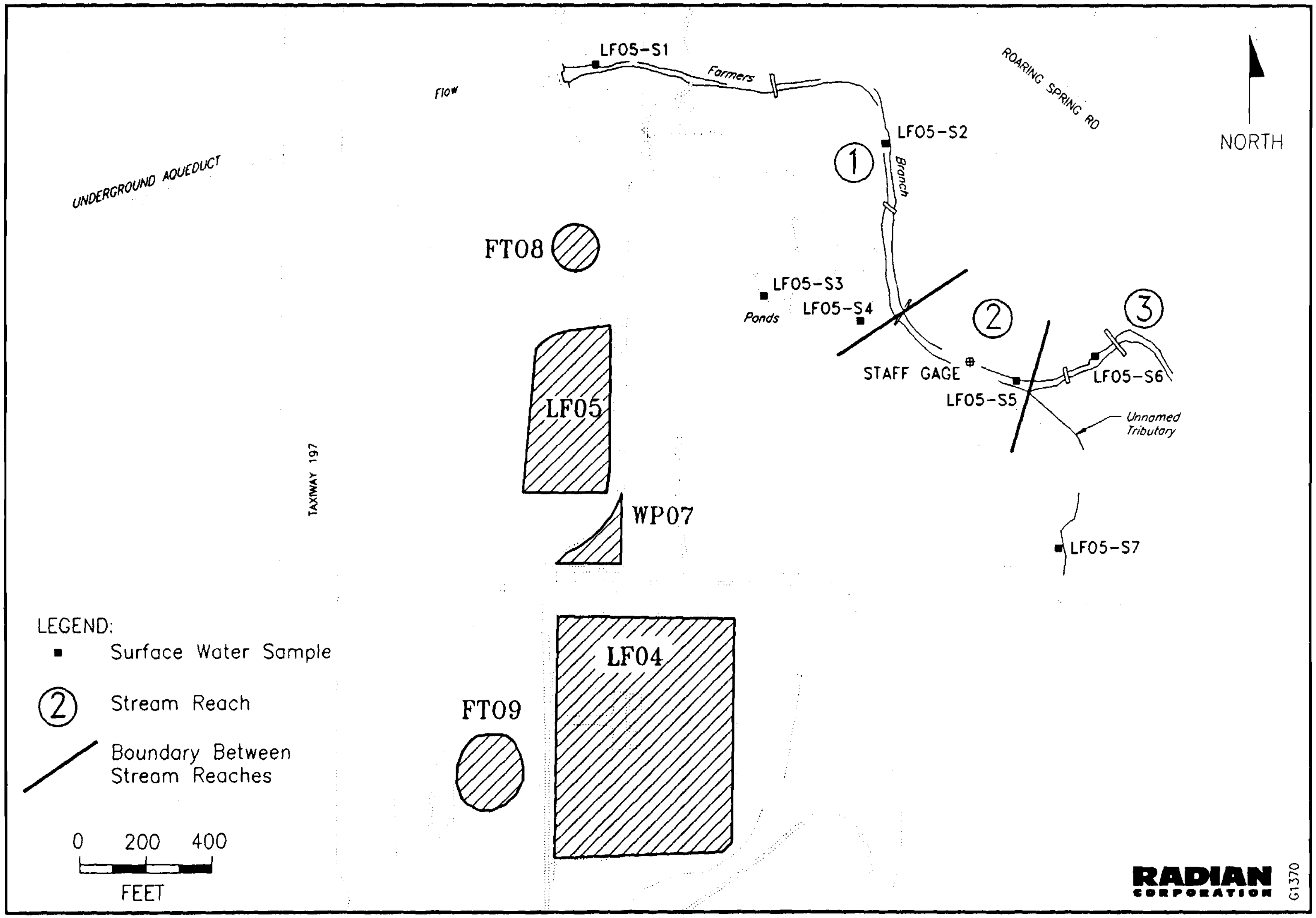

Figure 5-9. Surface Water Sampling Points and Three Divided Reaches of Farmers Branch, Flightline Area, Carswell AFB, Texas

The reason for this is the Upper Zone Aquifer outcrops in a broad cutbank of Farmers Branch across the entirety of this reach, and the ground water is therefore not in direct communication with the stream. Instead, water from the Upper Zone emanates from a series of seeps along the cutbank, and percolates down the face of the cutbank into a series of pools which are located on limestone bedrock of the Goodland/Walnut Formation. As in the case of the upper reach, this allows for significant volatilization and evapotranspiration to occur, and would consequently strip most of the contaminants from the water prior to any possible mixing with surface water from Farmers Branch. It is likely that minor amounts of contaminants from both reaches may migrate downstream to the third reach.

Significant concentrations of TCE and 1,2-DCE in the ground water (on the order of 1300 $\mu g/L$ and 280 $\mu g/L$, respectively) are discharging as surface water in the vicinity of surface-water sample location LF05-S7. This water, in turn, discharges directly into Farmers Branch in the third reach, and constitutes the principal pathway for off-site and off-base migration. Since the unnamed tributary to Farmers Branch is considered equivalent to a direct discharge of the main TCE plume, the discharge of the tributary and also Farmers Branch were calculated to determine the effects of dilution as the two bodies intersect. This was done using the simple relationship:

$$Q = vA$$

where: Q = discharge
v = velocity
A = cross-sectional area

Applying this equation to values obtained in the field, the slow moving tributary had an estimated discharge of approximately 0.2 cubic feet per second (cfs) or about 129,000 gallons per day (gpd). In contrast, at the time of field measurement, the discharge of Farmers Branch upstream of the tributary was approximately 6 cfs, or about 3,900,000 gpd. This translates into a dilution factor of about 30, suggesting that contaminant concentrations in Farmers Branch would be thirty times lower than those occurring in the unnamed tributary. Surface-water sampling results confirmed this, as the TCE concentrations between samples LF05-S7 and LF05-S6 (1400 μg/L and 43 μg/L) appear diluted by a factor of 33 and 1,2-DCE concentrations between the same two locations (310 μg/L at LF05-S7 and 8.4 μg/L at LF05-S6) appear diluted by a factor of 37.

It may be concluded that as the most highly contaminated portion of ground-water plume continues migrating to the east, the concentrations of organic contaminants detected in the unnamed tributary, and hence in Farmers Branch, may increase proportionately. However, plume degradation by physical, chemical and biological factors may result in transport of contaminants off-site remaining fairly constant over the next few years. Currently, TCE migration off-site in Farmers Branch is estimated at 45 μg/L and 1,2-DCE migration off-site is estimated at 8.4 μg/L. There are insufficient data available to estimate the concentration of these contaminants in reaches of Farmers Branch outside the Flightline Area. However, volatilization will reduce the organic contaminant content of Farmers Branch before its ultimate discharge into the Trinity River.

6.0 BASELINE RISK ASSESSMENT

A baseline risk assessment was performed for the Flightline Area. Site FT09 (Fire Department Training Area 2) was not included in the risk assessment because a remedial action has already been selected (Radian, 1990) and the detailed design and specifications are in preparation. The selected remedial action will effectively eliminate this site as a source of contaminants.

6.1 Summary of Indicator Chemicals

Sampling and analysis of soil and water in the Flightline Area has resulted in a large number of chemical substances being detected. Conducting a baseline risk assessment that included every detected chemical would be unnecessarily time consuming. The baseline risk assessment of the Flightline Area is therefore based on selected indicator chemicals that pose the greatest potential risks at the site, a methodology endorsed by the U.S. EPA for evaluation of the health impacts of waste sites (U.S. EPA, 1986a).

Indicator chemicals were selected from approximately 80 chemicals known to be present at the site according to Health Evaluation Manual (U.S. EPA, 1986a). The selection process, based in both 1988 and 1990 sampling and analyses performed on the soil, ground water, and surface water in the Flightline Area, resulted in the indicator chemicals listed below. All data generated in the 1988 program are summarized and discussed in the IRP Stage 2 Final Draft RI/FS (Radian, 1989) and are provided in data tables in the IRP Stage 2 ITIR (Radian, 1988). The data from the 1990 study are presented in the ITIR (Radian, 1990d) and corresponding data quality discussions are presented in Section 4.1 of this report.

Metals	Semivolatile Organic Compounds	Volatile Organic Compounds (VOCs)
Antimony	Bis(2-ethylhexyl)-phthalate	Benzene
Arsenic		Chloroform
Barium		1,2-Dichloroethane

Beryllium	Methylene chloride
Cadmium	Tetrachloroethene
Chromium	Toluene
Lead	Trichloroethene
Nickel	Vinyl chloride
Selenium	
Silver	

Some of the indicator chemicals, particularly those detected at very low concentrations, may be the result of matrix interferences or sample cross-contamination. No analysis for semivolatile compounds was performed in 1990 and the low levels of phthalate detected previously are suspected as being artifacts of sampling or laboratory contamination. As already discussed, dissolved metals concentrations in ground water and surface water samples, determined only in the 1990 effort, were all below MCLs and do not suggest a metals contamination problem. Nevertheless, all of the identified indicator chemicals were included in the risk assessment process to ensure a conservative (stringent-case) evaluation of possible health risks.

6.2 Source and Release Characterization

Possible mechanisms of contaminant release from Landfill 4 (LF04), Landfill 5 (LF05) and the Waste Burial Area (WP07) include: 1) volatilization to the air, 2) fugitive dust generation, 3) leachate to ground water, 4) surface runoff, 5) direct release to surface water, and 6) contaminated ground-water discharge to surface water.

6.2.1 Volatilization to the Air

VOCs present in the soil are subject to volatilization to the air by virtue of high vapor pressures. Semivolatile organic compounds generally have very low vapor pressures and are not subject to volatilization. Most metals are nonvolatile as well. Indicator chemicals detected in the Flightline Area which can volatilize include benzene, chloroform, 1,2-dichloroethane, methylene chloride, tetrachloroethene, toluene, trichloroethene, and vinyl chloride.

Estimated emission rates based conservatively on maximum concentrations detected in the soil or water samples from the Flightline Area are:

Indicator Chemical	Emission Rate (grams/second)
Benzene	2.25×10^{-5}
Chloroform	1.58×10^{-6}
1,2-Dichloroethane	1.07×10^{-7}
Methylene chloride	2.85×10^{-5}
Tetrachloroethene	1.25×10^{-7}
Toluene	6.79×10^{-7}
Trichloroethene	3.22×10^{-4}
Vinyl chloride	7.51×10^{-5}

The methodology used to estimate emission rates is described in the IRP Stage 2 RI/FS Final Draft Report (Radian, 1989).

6.2.2 Fugitive Dust Generation

Contaminants must be present in exposed soil to be subject to fugitive dust generation. Because wastes in these IRP sites are buried and the surface is vegetated, contaminants present in the soil are not subject to significant fugitive dust generation.

6.2.3 Leachate to Ground Water

Indicator chemicals detected in ground-water samples from downgradient monitor wells in the Flightline Area include: antimony, arsenic, barium, beryllium, cadmium, chromium, lead, nickel, selenium, silver, bis(2-ethylhexyl)phthalate, benzene, chloroform, methylene chloride, tetrachloroethene, toluene, trichloroethene, and vinyl chloride.

6.2.4 Surface Runoff

Contaminants must be exposed at the land surface to be subject to significant surface runoff during precipitation. Because Landfill 4 and the Waste Burial Area were covered and vegetated after disposal operations ceased, and because both are relatively flat, contaminants present in the soil are not subject to significant surface runoff. Landfill 5 was also covered and vegetated after disposal activities ceased. However, because Landfill 5 was constructed above ground level and is adjacent to the small tributary to Farmers Branch, there is a greater potential for surface runoff of contaminants than for the other two sites.

6.2.5 Discharge to Surface Water

There is no direct discharge of contaminants to surface water. However, there is indirect discharge in the form of contaminated ground water discharging to Farmers Branch, the small tributary, and the two golf course ponds in the Flightline Area.

6.3 Transport and Fate of Contaminants

Primary environmental transport media for chemical substances in the environment include the air, surface water, ground water, and soil. Intermedia transfers can occur and may be critical at some sites. For example, chemicals in the air can settle to the ground, mix in the soil, deposit on edible plant matter, or deposit on surface water. Chemicals in the ground water and soil are subject to uptake by edible plants.

The Flightline Area sites potentially release VOCs to the air via volatilization and all identified indicator chemicals to the ground water via waste leaching. The main mechanism for contaminant release to surface water is by Upper Zone ground-water discharge. Potentially significant contaminant transport and fate mechanisms in the air and ground-water media include: 1) air dispersion, 2) ground-water migration, 3) discharge to the surface,

4) transport in surface water, and 5) subsequent uptake by plants and animals.

6.3.1 Air Dispersion

Emission of VOCs from the Flightline Area IRP sites occurs at ground level in the gaseous phase. The gases disperse in the ambient atmosphere according to local meteorological conditions. The User's Network for Applied Modeling of Air Pollutants - Version 6 (UNAMAP 6) Industrial Source Complex Long Term (ISCLT) dispersion model (U.S. EPA, 1987) was used to calculate annual ground level concentrations of each indicator chemical. The ISCLT model was selected for use because it is approved by the U.S. EPA and is capable of evaluating the range of situations encountered in this assessment. The important model capabilities include:

- Calculation of dispersion from both point and area sources;
- Urban dispersion;
- Efficient calculation of annual average concentrations;
- Evaluation of both a receptor grid and discrete receptor points; and
- Simultaneous evaluation of multiple source impacts and individual source impacts.

The ISCLT model accepts a summarized statistical array of meteorological conditions based on data for a year or more. Model output consists of one average concentration for each source and/or source group at each input receptor.

The model was run using urban mode 3 as recommended by EPA for developed areas. Wind profile exponents, vertical potential temperature gradients, and the plume rise equation all affect source plume rise and were set to the EPA-recommended default values. The choice of these options had little or no effect on model results since all sites were modeled with no significant plume rise. A complete description of the modeling methodology is discussed in the IRP Stage 2 RI/FS Final Draft Report (Radian, 1989).

To model the dispersion of contaminants in the air from the sites to selected receptor locations requires the use of simplifying assumptions to simulate the atmospheric environment. In reality, dispersion of contaminants in the ambient air involves numerous complex processes that are not always addressed by available models. Some simplifying assumptions may lead to either overestimates or underestimates of exposures. Generally, the ISCLT model, and the modeling methodology used in the assessment, incorporate conservative assumptions that will result in overestimates of exposure. For example, model inputs included emission rates calculated using the highest measured concentration at each site regardless of depth or whether the sample was aqueous or soil. Maximum ground-level concentrations estimated by the ISCLT model were assumed to be inhaled continuously, 24 hours per day, for 70 years, at the receptor locations. The successive use of conservative assumptions is likely to produce estimated exposures that are higher than the reasonable maximum exposure that is likely to occur.

6.3.2 Ground-Water Migration

In the Flightline Area, ground water in the Upper Zone occurs in sand and gravel deposits that are underlain by relatively impermeable and dry limestone/shale bedrock. Hydraulic head in the Upper Zone Aquifer decreases toward Farmers Branch, indicating that ground-water flow is also toward Farmers Branch. The bed of Farmers Branch is cut into the same bedrock that forms the base of the Upper Zone; therefore ground water is expected to discharge directly to Farmers Branch or to be consumed by evapotranspiration as it exits the Upper Zone materials near the creek. This in fact is the case as ground water is continually seeping from the cut-bank face of the creek and ponding on the limestone bedrock that forms the creek bed. Ground-water flow is generally not toward the base perimeter in this area. Therefore, migration of contaminants from the Flightline Area to any domestic or agricultural use wells in the area is unlikely.

6.3.3 Transport in Surface Water

Since VOCs remain in a gaseous state and do not deposit on the ground, surface water in the area is not subject to contamination via emissions to the air from the Flightline Area. Contaminants which reach Farmers Branch via ground-water migration (or surface runoff from Landfill 5) are subject to dilution and movement with the surface flow downstream to the West Fork of the Trinity River located east of the base. The West Fork of the Trinity River is downstream of Lake Worth, which is the source of drinking water for Fort Worth and Carswell AFB. Thus the path of surface water drainage precludes the transport of contaminants from the Flightline Area to the sole surface water source of drinking water in the area. Any VOCs present in surface water would probably volatilize to the air, thus leading to decreasing VOC concentrations with increasing distance downstream.

6.3.4 Uptake by Plants and Animals

Food crops, including commercial agricultural crops and backyard gardens, are subject to accumulation of contaminants migrating from the Flightline Area IRP sites via root uptake of any contaminants present in the water used for watering or irrigation. Migration of ground water to a surface water source used for watering or irrigation is the only significant pathway for contaminants to move from the Flightline Area to plants. However, farming operations in the area generally rely on natural precipitation or irrigation of crops with ground water (South, J., 1988), which eliminates this potential pathway for human exposure. Since emissions to the air from the Flightline Area would be limited to VOCs which remain in a gaseous state in ambient air, they will not deposit on above-ground plant surfaces or on the soil or surface water so as to be available for root uptake.

Terrestrial organisms, including farm animals and wildlife, are potentially subject to accumulation of contaminants originating in the Flightline Area sites by: 1) inhalation of ambient air, and 2) ingestion of surface water contaminated via ground-water migration. As discussed above, farm operations in the area do not use surface water to irrigate crops.

Therefore, farm animals are not subject to ingestion of plants irrigated or watered with surface water contaminated via ground-water discharge.

Aquatic organisms, including fish, are subject to accumulation of contaminants by uptake from surface water contaminated via ground-water discharge/surface transport. Contaminants can bioaccumulate in the food chain of both terrestrial and aquatic organisms.

6.4 Exposure Pathways

Figure 6-1 depicts potential pathways for contaminants to move from the Flightline Area to human exposure points. A major potential exposure pathway, ground water ingestion, is not applicable to Upper Zone ground water in the Flightline Area. The ground-water discharges directly to the Farmers Branch, which flows to the West Fork of the Trinity river downstream of Lake Worth. Lake Worth is the source of drinking water for Fort Worth and Carswell AFB. Ground-water flow is generally not toward the base perimeter in this area. In addition, ground water present in the Upper Zone, in general, is not hydraulically connected to the underlying aquifers (CH2M Hill, 1984). For the most part, it is not economical to develop ground water from the alluvium because of the water's limited distribution and susceptibility to surface pollution. The community of River Oaks, immediately east of Carswell AFB, at one time had supply wells that developed water from the alluvial deposits at a location near the USAF Hospital. However, the wells were abandoned when Carswell AFB purchased the property. An inventory of water wells located within one mile of the Carswell AFB boundary was conducted (Radian, 1989). Figure 6-2 shows the locations of the existing and abandoned wells identified from Texas Water Commission records. Thirty-nine wells were identified, but none were completed in the Upper Zone aquifer.

Fugitive dust generation and soil ingestion are also considered incomplete pathways because wastes in the Flightline Area IRP sites are buried and the surface is vegetated. Fugitive dust generation was considered for Fire Department Training Area 2, (Site FT09); however, since a remedial design

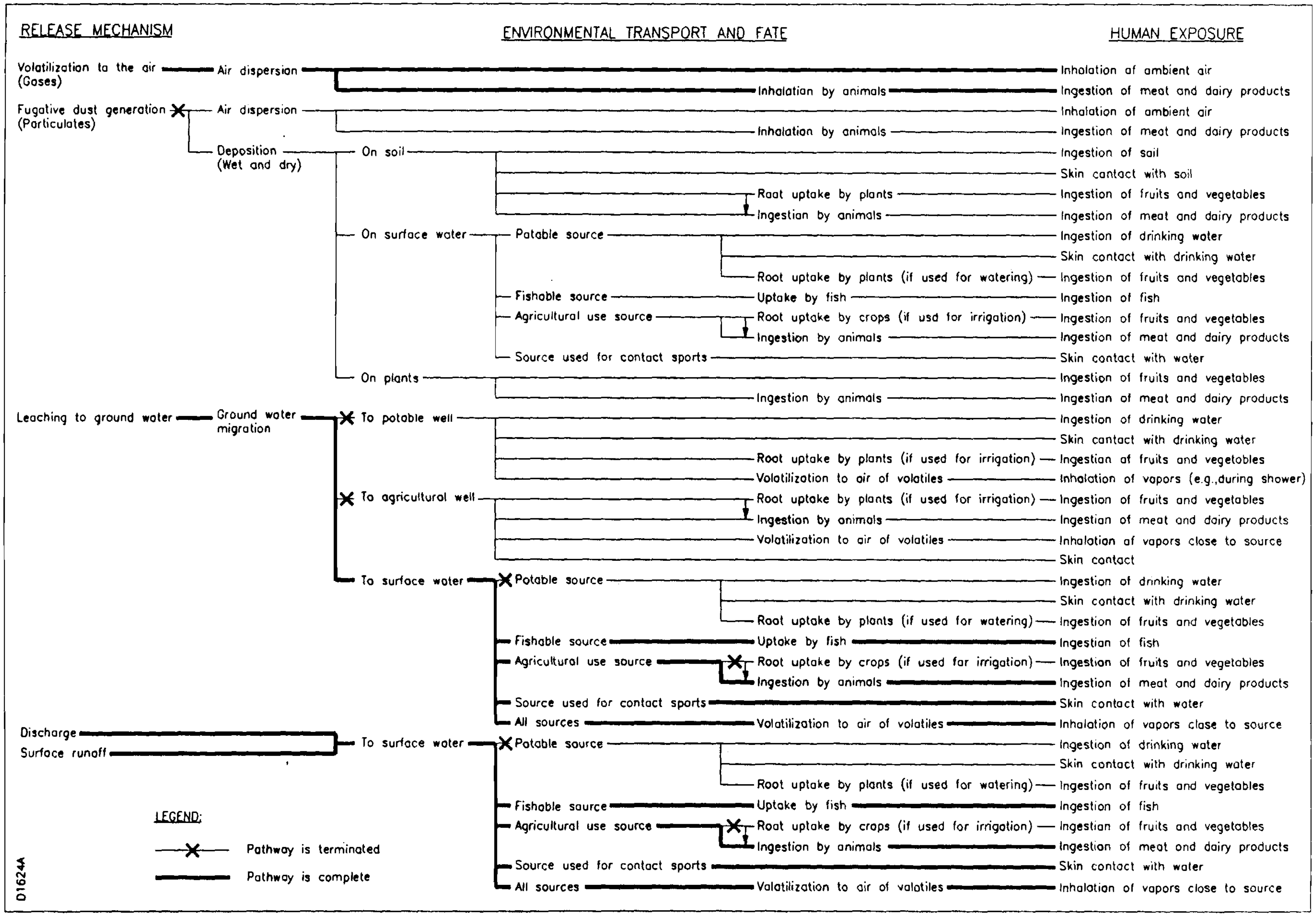

Figure 6-1. Potential Pathways to Human Exposure from the Flightline Area

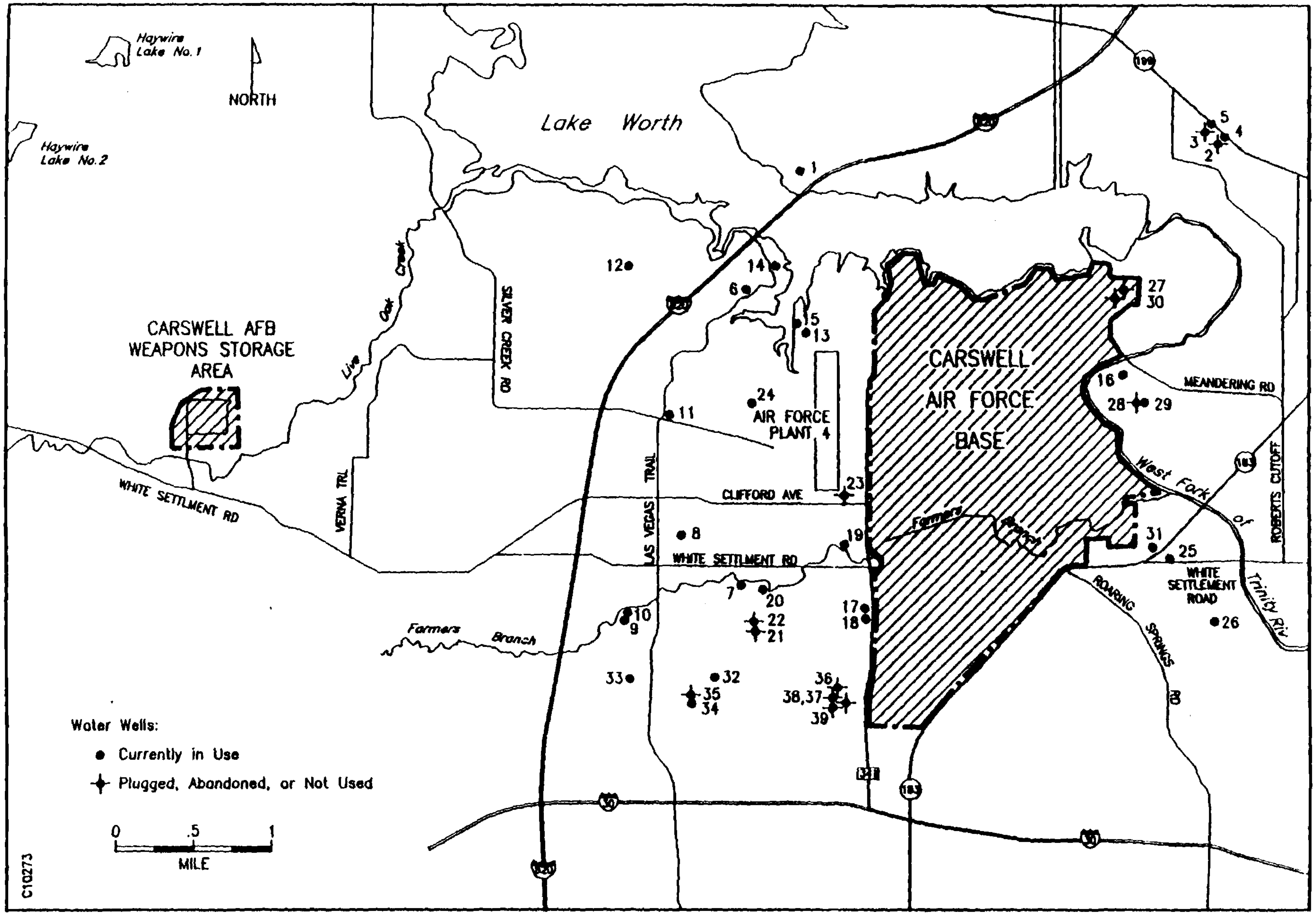

Figure 6-2. Location of Water Wells Within 1 Mile of Carswell AFB, Texas

which includes excavation and capping has already been selected for this site, it is no longer at issue. Remaining pathways include:

1. Volatilization to the air/air dispersion/inhalation of ambient air;

2. Volatilization to the air/air dispersion/inhalation by animals/ingestion of meat and dairy products;

3. Leaching to ground water/ground-water migration to surface water (fishable source)/uptake by fish and other aquatic organisms/ingestion of aquatic organisms;

4. Leaching to ground water/ground-water migration to surface water (agricultural use source)/ingestion by animals/ingestion of meat and dairy products;

5. Leaching to ground water/ground-water migration to surface water (source used for contact sports)/skin contact with water; and

6. Leaching to ground water/ground-water migration to surface water/volatilization of volatiles/inhalation of vapors close to source.

Contaminant contributions to surface water used for fishing, for agriculture, for contact water sports, or from which VOCs can volatilize, can also potentially result from surface runoff from Landfill 5 to a Farmers Branch tributary.

6.5 Identification of Receptors

Based on available exposure pathways, potential human receptors for exposure to contaminants migrating from the Flightline Area include: 1) persons residing and/or working in nearby areas, particularly downwind of the site; 2) persons ingesting meat and dairy products from animals exposed to contaminants in the ambient air or contaminated surface water; 3) persons ingesting fish or other aquatic organisms exposed to contaminated surface water; and 4) persons swimming or participating in other contact sports in contaminated water.

Potential wildlife receptors include: 1) terrestrial organisms with habitats close to the Flightline Area that inhale ambient air and ingest surface water, particularly from Farmers Branch, its unnamed tributary and/or the golf course ponds, and 2) aquatic organisms in the on-base surface water bodies and the West Fork of the Trinity River.

6.6 Quantification of Exposures

6.6.1 Inhalation Exposure

Inhalation of ambient air is the most direct exposure pathway for contaminants to move from the Flightline Area to human receptors. Table 6-1 presents the on-site maximum and off-site maximum predicted annual ambient air concentrations resulting from estimated Flightline Area emissions, and predicted concentrations at several discrete locations: site of the proposed base day care center, which is central to the largest on-base residential area, the Fort Worth National Fish Hatchery, and the closest dairy and beef operations. The table also lists Texas Air Control Board (TACB) Health Effects Screening Levels (ESLs) which the agency uses to evaluate the impacts of air contaminants. TACB screening levels are based on occupational exposure limits [American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), Occupational Health and Safety Administration (OSHA) standards, or National Institute for Occupational Safety and Health (NIOSH) recommendations], odor nuisance potential, vegetation effects, or corrosion effects. Generally the annual ESL corresponds to 0.1% of the lowest occupational exposure limit.

The maximum predicted annual average concentrations resulting from estimated Flightline Area emissions for benzene, chloroform, 1,2-

TABLE 6-1. PREDICTED ANNUAL AVERAGE AMBIENT AIR CONCENTRATIONS RESULTING FROM ESTIMATED FLIGHTLINE AREA EMISSIONS[a]

Contaminant	Predicted Annual Average Ambient Air Concentration (ug/m^3)						TACB Annual Effects Screening Level[b] (ug/m^3)
	On-Site Maximum	Off-Site Maximum	Day Care	Fish Hatchery	Dairy Operation	Beef Operation	
Benzene	2.3×10^{-4}	3.2×10^{-5}	7.2×10^{-5}	9.7×10^{-7}	2.0×10^{-7}	7.3×10^{-8}	3
Chloroform	8.7×10^{-6}	8.8×10^{-7}	2.4×10^{-6}	5.5×10^{-8}	1.1×10^{-8}	4.0×10^{-9}	10
1,2-Dichloroethane	1.1×10^{-6}	1.5×10^{-7}	3.4×10^{-7}	4.6×10^{-9}	$<10^{-9}$	$<10^{-9}$	4
Methylene chloride	1.6×10^{-4}	1.6×10^{-5}	4.4×10^{-5}	9.9×10^{-7}	2.8×10^{-7}	7.5×10^{-8}	26
Tetrachloroethene	6.9×10^{-7}	6.9×10^{-8}	1.9×10^{-7}	4.0×10^{-9}	1.0×10^{-9}	$<10^{-9}$	33.5
Toluene	9.1×10^{-6}	4.8×10^{-7}	1.3×10^{-6}	3.3×10^{-8}	7.0×10^{-9}	3.0×10^{-9}	375
Trichloroethene	3.6×10^{-3}	2.3×10^{-4}	5.9×10^{-4}	1.5×10^{-5}	3.1×10^{-6}	1.1×10^{-6}	135
Vinyl chloride	1.6×10^{-3}	3.1×10^{-5}	6.5×10^{-5}	3.0×10^{-6}	6.0×10^{-7}	2.1×10^{-7}	10

[a]Individual contributions from Landfill 4, Landfill 5, and the Waste Burial Area, as reported in Radian, 1988 have been added to derive estimated annual average ambient on concentrations associated with the Flightline Area.

[b]November 15, 1990.

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dichloroethane, methylene chloride, tetrachloroethene, toluene, trichloroethene, and vinyl chloride are lower than the conservative TACB Effects Screening Levels by orders of magnitude ranging from 4 to 8.

6.6.2 Ingestion Exposure

Potential ingestion exposures include ingestion of meat and dairy products from animals exposed to contaminants in the ambient air or contaminated surface water, and fish exposed to contaminated surface water. The Flightline Area contributes very low concentrations of VOCs to the ambient air. At the sites of the nearest dairy and beef operations, concentrations are predicted on the order of 10^{-7} $\mu g/m^3$ and lower (see Table 6-1). Although cows will absorb inhaled VOCs, these compounds do not tend to accumulate in milk or edible tissues which humans might consume. Likewise, livestock consumption of surface water containing contaminants originating from the Flightline Area is theoretically possible, if livestock consumes water from the West Fork of the Trinity River; however, any exposure can be expected to be minimal due to the distance from Carswell AFB to the nearest dairy and beef operations. Consumption of locally produced beef and dairy products therefore does not represent a significant pathway of human exposure to contaminants originating from the Flightline Area.

The most significant fishable resource in the vicinity of Carswell AFB is Lake Worth. The Fort Worth National Fish Hatchery is located at the western end of the lake. Since there is no available pathway for contaminants to move from the Flightline Area to Lake Worth, there is no potential for human exposure to contaminants originating at the Flightline Area via ingestion of fish caught in the lake. There is some theoretical potential for fish in the West Fork of the Trinity River to accumulate contaminants from the Flightline Area in the area downstream of the intersection of Farmers Branch with the river. However, contaminant contributions to the river from the Flightline Area via contaminated ground-water discharge to Farmers Branch are likely to be very minimal due to the distance between the site and the river (approximately one mile), dilution, volatilization, and the low concentrations of contaminants in ground water. Therefore, concentrations of contaminants in the river which originate from the Flightline Area were not established.

6.6.3 Dermal Exposure

The potential for skin contact with contaminants originating from the Flightline Area is limited to exposure while swimming in (or otherwise in contact with) contaminated surface water. Lake Worth is the most highly utilized surface water body for swimming and other water contact sports in the area. Again, since there is no available pathway for contaminants to move from the Flightline Area to Lake Worth, there is no potential for human exposure to contaminants originating from the Flightline Area via skin contact with lake water. As discussed above, contaminant contributions to the West Fork of the Trinity River from the Flightline Area are theoretically possible but likely to be very minimal; therefore, skin contact with river water is not considered a significant exposure pathway for this site. Skin contact with water in Farmers Branch, which is not amenable to swimming or other contact activities other than possibly wading, could contribute to dermal exposure. The exposure potential from this pathway was not quantified.

6.7 Threat to Human Health

6.7.1 Noncarcinogenic Risks

Table 6-2 shows estimates of average daily inhalation exposure (in mg/kg body weight/day) at the location of the on-site and off-site maximum predicted annual average concentration, and at the proposed on-site day care facility, and compares these values with inhalation Reference Doses (RFDs) for chronic (long-term) exposure. An inhalation RFD is an estimate of the dose of a chemical that can be inhaled daily for a lifetime without producing adverse noncarcinogenic health effects. The derivation of RFDs (Formerly Acceptable Daily Intakes--ADIs) used in this assessment is discussed in the IRP Stage 2 RI/FS Final Draft Report (Radian, 1989).

TABLE 6-2. ESTIMATED ANNUAL AVERAGE DAILY INHALATION EXPOSURES FOR CONTAMINANTS FROM THE FLIGHTLINE AREA

Contaminant	Inhalation Reference Dose[a] (mg/kg/day)	On-Site Maximum: Inhalation Exposure[c] (mg/kg/day)	On-Site Maximum: Hazard Index[d]	Off-Site Maximum: Inhalation Exposure[c] (mg/kg/day)	Off-Site Maximum: Hazard Index[d]	Day Care: Inhalation Exposure[b] (mg/kg/day)	Day Care: Hazard Index[c]
Benzene	$3.2x10^{-1}$[b]	$6.57x10^{-8}$	$2.01x10^{-7}$	$9.14x10^{-9}$	$2.86x10^{-8}$	$2.01x10^{-9}$	$6.43x10^{-8}$
Chloroform	$1.0x10^{-2}$	$2.48x10^{-9}$	$2.43x10^{-7}$	$2.53x10^{-10}$	$2.53x10^{-9}$	$6.95x10^{-10}$	$6.95x10^{-8}$
1,2-Dichloroethane	$2.7x10^{-3}$[b]	$3.14x10^{-10}$	$1.16x10^{-7}$	$4.29x10^{-11}$	$3.30x10^{-8}$	$9.7x10^{-11}$	$7.47x10^{-8}$
Methylene chloride	$8.6x10^{-1}$	$4.48x10^{-8}$	$5.21x10^{-8}$	$4.56x10^{-9}$	$5.30x10^{-9}$	$1.25x10^{-8}$	$1.45x10^{-8}$
Tetrachloroethene	$1.0x10^{-2}$	$1.96x10^{-10}$	$1.96x10^{-8}$	$2.00x10^{-11}$	$2.00x10^{-9}$	$5.50x10^{-11}$	$5.50x10^{-9}$
Toluene	$5.7x10^{-1}$	$2.60x10^{-9}$	$4.56x10^{-9}$	$1.37x10^{-10}$	$2.41x10^{-10}$	$3.71x10^{-10}$	$6.52x10^{-10}$
Trichloroethene	$2.46x10^{-2}$[b]	$1.02x10^{-6}$	$4.18x10^{-5}$	$6.57x10^{-8}$	$2.67x10^{-6}$	$1.68x10^{-7}$	$6.85x10^{-6}$
Vinyl chloride	$1.3x10^{-3}$[b]	$4.51x10^{-7}$	$3.47x10^{-4}$	$8.86x10^{-9}$	$6.81x10^{-6}$	$1.86x10^{-8}$	$1.43x10^{-5}$
TOTAL HAZARD INDEX			$3.89x10^{-4}$		$9.55x10^{-6}$		$2.14x10^{-5}$

[a]Estimate of the dose of a chemical that can be inhaled daily for a lifetime without producing adverse noncarcinogenic health effects. The source for the listed values in the U.S. EPA Health Effects Assessment Summary Tables (HEAST), Fourth quarter FY 1990 (EPA, 1990), unless otherwise noted. If an inhalation RfD was not available, the oral RfD was used. If an inhalation reference concentration (RfC) was listed in mg/m^3 and not an RfD, the RfC was covnerted to an RfD assuming a 70 kg person inhales 20 m^3/day. The HEAST values used are listed on the EPA Integrated Risk Information system (IRIS) or IRIS input is pending.

[b]Derived for this assessment (see Radian, 1989).

[c]Inhalation exposure assumes inhalation for 24 hours/day of predicted annual average ambient concentrations by an individual with an average body weight of 70 kg and with an average inhalation rate of 20 m^3/day.

[d]Inhalation Exposure/Inhalation Reference Dose.

Average daily inhalation exposures for benzene, chloroform, 1,2-dichloroethene, methylene chloride, tetrachloroethene, toluene, trichloroethene, and vinyl chloride are lower than pollutant-specific RFDs in all cases by more than three orders of magnitude. The total hazard index is significantly less than one at all sites, indicating that the threat of noncarcinogenic health effects of inhalation exposure to contaminants originating from the Flightline Area is not significant.

6.7.2 Carcinogenic Risks

Inhalation Risk--Of the eight indicator chemicals that might be released to the air from the Flightline Area, seven are potential carcinogens. These are: benzene, chloroform, 1,2-dichloroethane, methylene chloride, tetrachloroethene, trichloroethene, and vinyl chloride. Cancer potency estimates developed by EPA were used in conjunction with total daily contaminant doses to develop estimates of incremental individual cancer risk:

$$\text{Individual Cancer Risk} = \underset{(\text{mg/kg/day})}{\text{Total Daily Dose}} \times \underset{(\text{mg/kg/day})^{-1}}{\text{Cancer Potency}}$$

Incremental individual cancer risk is the increased probability of developing cancer in one's lifetime.

Table 6-3 shows estimates of incremental individual cancer risk for the maximum on-site and maximum off-site exposed individual and for an individual inhaling ambient concentrations in the immediate vicinity of the proposed day care facility continuously for a lifetime. These risks, the highest of which is one in 10 million, can be dismissed as inconsequential.

Ingestion Risk--The potential for ingestion exposure to contaminants originating from the Flightline Area is remote and likely to be minimal. The risk of ingestion exposure was therefore not quantified.

Dermal Risk--The potential for dermal exposure to contaminants originating from the Flightline Area is also minimal. Unless an individual

TABLE 6-3. ESTIMATED INDIVIDUAL CANCER RISK ASSOCIATED WITH INHALATION OF POTENTIAL CARCINOGENS FROM THE FLIGHTLINE AREA

Contaminant	Inhalation Slope Factor[a] $(mg/kg/day)^{-1}$	Individual Cancer Risk[b] On-Site Maximum Exposed Individual	Off-Site Maximum Exposed Individual	Individual Exposed at Day Care Facility
Benzene	2.9×10^{-2}	1.9×10^{-9}	2.7×10^{-10}	5.8×10^{-10}
Chloroform	8.1×10^{-2}	2.0×10^{-10}	2.0×10^{-11}	5.6×10^{-11}
1,2-Dichlorethane	9.1×10^{-2}	2.9×10^{-11}	3.9×10^{-12}	8.8×10^{-11}
Methylene chloride	1.4×10^{-2}	6.3×10^{-10}	6.4×10^{-11}	1.8×10^{-10}
Tetrachloroethene	1.8×10^{-3}	3.5×10^{-13}	3.6×10^{-14}	9.9×10^{-14}
Trichloroethene	1.7×10^{-2}	1.7×10^{-8}	1.1×10^{-9}	2.6×10^{-9}
Vinyl chloride	2.9×10^{-1}	1.3×10^{-7}	2.6×10^{-9}	5.4×10^{-9}
TOTAL 70 Year Risk		1.5×10^{-7}	4.1×10^{-9}	8.9×10^{-9}

[a]See the IRP Stage 2 RI/FS Report (Radian, 1989) for discussion and documentation. Some values have been revised by EPA and revised values have been used. The source for the listed values in the U.S. EPA Health Effects Assessment Summary Tables (HEAST), Fourth Quarter FY 1990 (EPA, 1990). The values for benzene, chloroform, 1,2-dichloroethane, and methylene chloride are listed on the EPA Integrated Risk Information System (IRIS). The values for tetrachloroethene and vinyl chloride were derived from unit risk values listed in HEAST, assuming a 70 kg person inhales 20 m^3/day. The value for trichloroethene is listed in HEAST but was removed from IRIS pending further review.

[b]Risk calculation assumes inhalation for 24 hours/day for a 70 year lifetime of predicted annual average ambient concentrations by an individual with an average body weight of 70 kg and with an average inhalation rate of 20 m^3/day.

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immersed frequently in the waters of Farmers Branch for a long period of time, skin contact exposure can be considered insignificant. The risk of dermal exposure was therefore not quantified.

6.8 Threat to Wildlife

Contaminants migrating from the Flightline Area, as discussed previously, pose some risk to terrestrial wildlife that use Farmers Branch, its small tributary, and the golf course ponds as a source of drinking water, as well as aquatic organisms in these surface water bodies. In the past, there have been some instances of fish kills in Farmers Branch and in the small ponds near Building 233. Table 6-4 compares the maximum values of indicator chemicals detected in the Flightline Area surface water samples with EPA water quality criteria (where available) for aquatic life in fresh water.

The only organic indicator chemical that has an established criterion (LOEL - lowest observed effect level) is TCE. The maximum detected concentration of TCE in surface water samples is 15 times less than the chronic LOEL for fresh water aquatic species.

Two metals, lead and silver, were detected in concentrations greater than the ambient fresh water chronic criteria. Silver was detected three times (twice in golf course ponds and once in Farmers Branch). However, all three detectable concentrations occurred in unfiltered samples and all were less than five times the method detection limit. All dissolved silver concentrations were below the method detection limit (10 μg/L). Because the detection limit is higher than the chronic criterion for aquatic life in fresh water, it is not possible to determine whether any dissolved silver concentrations actually exceeded the chronic criterion.

Lead was detected in all four water samples from Farmers Branch and from one of the golf course ponds. The only detected concentration exceeding the chronic criterion, however, was in the golf course pond sample. The accuracy of the reported lead concentration is questionable as the corresponding dissolved lead concentration was roughly three times greater than the

TABLE 6-4. COMPARISON OF MAXIMUM DETECTED SURFACE WATER INDICATOR CHEMICAL CONCENTRATIONS WITH EPA WATER QUALITY CRITERIA

Indicator Chemical	Maximum Detected Concentration (µg/L)	Fresh Acute (µg/L)	Fresh Chronic (µg/L)
TCE	1,400.0	46,000*	21,000*
Vinyl chloride	3.7	--	--
Arsenic (metal)	4.8		
- Pentavalent	--	850*	48*
- Trivalent	--	360	190
Barium	210.0	--	--
Lead	29.0	330**	12.9**
Silver	23.0	26.9**	0.12

*Insufficient data to develop criteria. Value presented is the LOEL - Lowest Observed Effect Level.

**Hardness Dependent Criteria (300 mg/L used).

--No criteria or LOEL available.

Source: U.S. EPA, Quality Criteria for Water 1986b. EPA 440/5-86-001. May 1, 1986.

total concentration which did not exceed the chronic criterion. All four samples collected from Farmers Branch contained lead in concentrations approaching the chronic criterion for fresh water aquatic life. One of these samples was collected from a reach of Farmers Branch upstream of any of the Flightline Area sites, so it appears that either natural background concentrations of lead in surface water are relatively high and/or Farmers Branch is receiving lead from an upstream source.

6.9 Defense Priority Model Evaluation

Radian used the Defense Priority Model (DPM) (Oak Ridge National Laboratory, 1987) to evaluate the Flightline Area (Sites LF04, LF05, WP07, and FT09) and four East Area IRP sites at Carswell AFB. DPM uses site-specific data to prioritize sites according to the severity of contamination. For the DPM, geologic and hydrologic data are used to indicate ground-water travel times and chemical analyses are analyzed using toxicological benchmarks to indicate risk to the local human population and natural environment.

Using information obtained during Stage Two of the Installation Restoration Program (IRP) at Carswell AFB, the DPM indicated the following ranking for the sites investigated (numbers in parentheses are the results of the DPM scoring and indicate relative rankings):

1. Unnamed Stream (20,760);
2. Flightline Area (19,381);
3. Landfill 1 (7,036);
4. Base Service Station (5,929); and
5. POL Tank Farm (4,584).

Radian has conducted extensive, detailed investigations of these sites and has produced a ranking of these sites which differs somewhat from the DPM ranking. The alternate ranking, which is based on the results of the Radian investigations is as follows:

1. Flightline Area;

2. Unnamed Stream;
3. POL Tank Farm;
4. Base Service Station; and
5. Landfill 1.

This discrepancy is probably because the DPM is designed as an unbiased tool for comparison and, therefore, has a simple, rigid format that does not take into account all factors which might be relevant to the ranking of a particular site. Indeed, the Introduction to the User's Manual for the DPM indicates the possibility of false high scores using the DPM. Radian's justification for giving the Flightline Area higher priority for remedial action relative to the Unnamed Stream is explained below. The DPM evaluation worksheets for the Flightline Area are provided as Appendix G.

<u>Flightline Area Versus Unnamed Stream</u>

Two factors strongly influenced the DPM ranking of the Flightline Area below that of the Unnamed Stream. The more important of these is the relatively low levels of metals (especially lead) detected in the Flightline Area, compared to the Unnamed Stream site. Also important was the difference in contaminant transport times because of the proximity of the Unnamed Stream to the base boundary and the Trinity River.

Radian assigns a higher ranking to the Flightline Area for several reasons, the most important of these being the relative concentrations of contaminants detected at these two sites. At the Unnamed Stream, no contaminants were detected at levels in excess of Maximum Contaminant Levels (MCLs). At the Flightline Area, however, TCE, vinyl chloride, tetrachloroethane and cis-1,2-dichloroethane were detected above current MCLs. Metals were detected in higher concentrations in the surface water samples from the Unnamed Stream, but none exceeded any regulatory concentration limit.

Another reason for assigning the Flightline Area a higher ranking is its size relative to the Unnamed Stream. The Flightline Area is much larger and contains a larger volume of contaminants than the Unnamed Stream site. It therefore presents a more complicated problem for remediation and a greater potential for future environment degradation.

7.0 SUMMARY AND CONCLUSIONS

This section summarizes the environmental contaminants detected in the Flightline Area, with special emphasis on the extent of contaminant migration, the mechanisms/pathways by which the contaminants are transported, and the level of risk the contaminants pose to the human health and environment. Also identified are existing data gaps, possible ways to address additional data requirements, and the objectives of any remedial actions conducted in the Flightline Area.

7.1 Summary of Contamination and Associated Risks

The following subsections present an overview of the main contaminants in the Flightline Area and the quantified risks associated with exposure to those contaminants.

7.1.1 Nature and Extent of Contamination

Ground Water

Environmental sampling conducted in the Flightline Area thus far has shown ground-water contamination by volatile organic compounds, particularly trichloroethene and vinyl chloride, to be the most widespread and significant problem. During the most recent ground-water investigation (April/May,1990), TCE was detected in concentrations exceeding the federal MCL in 27 of the 35 monitor wells sampled. Vinyl chloride exceeded its MCL in seven wells. Figures 5-2 and 5-4 show isoconcentration contour maps of TCE and vinyl chloride in the Upper Zone Aquifer at the Flightline Area.

As seen in Figure 5-2, ground-water sampling of the existing monitor well network has adequately defined of the northern and southern limits of the TCE plume; however, the extent of the plume to the east and west is currently unknown. The evidence generated to date suggests the TCE contamination is preferentially migrating along paleochannels that were identified during drilling and were mapped in the Flightline Area (Figure 5-7).

The maximum vertical extent of the TCE contamination, as well as all other contamination detected in the area, apparently corresponds to the upper surface of the Goodland/Walnut Formation, which underlies the Upper Zone sediments. The limestone and shale of the Goodland/Walnut Formations appear to be an effective barrier to downward migration of ground-water contaminants to deeper aquifers, because no contaminants were detected in the two Paluxy Aquifers (the sand aquifer directly under the Goodland/Walnut aquitard) monitor wells, one of which (P-2) is located near the center of the plume during the sampling performed in 1988.

Figure 5-4 shows the lateral extent of vinyl chloride detected in the Flightline Area Upper Zone ground water. The vinyl chloride contamination is less areally extensive and better defined than the TCE plume. Isoconcentration contour mapping of vinyl chloride detected in the Upper Zone ground water suggests Landfill 5 (LF05) is the principal source of the contamination.

Several other organic compounds were detected in the ground water from the Flightline Area monitor wells, most notably tetrachloroethene and cis-1,2-dichloroethene, but the concentrations of the compounds detected were either below MCLs or they have no established MCLs.

Multiple sources are apparently contributing the organic contaminants detected in the shallow ground water of the Flightline Area. Landfills 4 and 5, the Waste Burial Area, and to a lesser extent, Fire Training Area 2 appear to be contributing to the contamination, based on the concentration distribution of the volatile organic contaminants and the consistent nature of the detected contaminants and disposed wastes. However, repeated evidence of organic contamination in monitor wells located hydraulically upgradient of these sites suggests one or more additional off-base sources. Based on similar concentrations of TCE and related transformation products detected in upgradient wells on adjoining AF Plant 4 property, AF Plant 4 is considered the principal upgradient candidate source of the balance of the Flightline Area contamination.

Although several metals species were detected in concentrations greater than respective MCLs in unfiltered ground-water samples, it is probable that no metals contamination exists in the Upper Zone Aquifer at the site as no concentrations exceeding MCLs were reported in the dissolved metals analyses which most directly reflect ground-water chemistry.

Surface Water

Trichloroethene is the principal contaminant in the surface water of the Flightline Area. It was detected in all seven of the water samples taken in 1990, and exceeded the MCL in five of the samples. The highest detected concentration was in a sample from a small tributary to Farmers Branch (sample location LF05-S7 on Figure 5-9). There is strong evidence that the shallow ground water is providing the base-flow and the resulting contamination in this small stream. As with ground water, contamination observed in a reach of Farmers Branch upstream of the Flightline Area sites suggests an additional upstream contaminant source. The farthest downstream sample from Farmers Branch contained TCE in excess of the MCL. At this location, it appears that Farmers Branch is receiving a significant contaminant contribution from the previously mentioned tributary.

Vinyl chloride was the only other volatile organic compound detected in the surface water samples in excess of any MCLs and it was detected above the MCL in only one sample collected from the golf course ponds located adjacent to the golf course maintenance facilities.

The remaining volatile organic compounds detected in the surface water samples were the cis- and trans-isomers of 1,2-DCE. These compounds were commonly detected in the Flightline Area Upper Zone ground water.

No metals were detected above MCLs in any of the surface water samples collected in 1990. Water quality indicator results from the surface water samples were compared to the ground-water results. The strong similarity in the concentrations of cations and anions suggests that discharge of Upper Zone ground water is supplying a large portion of the surface water flow.

7.1.2 Fate and Transport

Fate of Contaminants

No dissolved metals concentrations in Upper Zone ground-water samples exceeded MCLs. Therefore only the persistence and transformation of organic contaminants were addressed. The ground-water contamination in the Flightline Area consists mainly of volatile chlorinated organic solvents, principally TCE with lesser amounts of chemically-related transformation compounds (Figure 5-1). The fate and persistence of these volatile organic compounds is controlled largely by the processes of diffusion and dispersion, adsorption and desorption, volatilization and subsequent resorption, and chemical and biological degradation.

Diffusion and dispersion are chemical and mechanical processes which contribute to dilution of specific contaminants within the body of the plume, but also result in enlargement of the plume. Because TCE and its related daughter products are generally classified as mobile solutes in water and therefore have a higher activity in the aqueous phase, their capacity for transport is only slightly retarded with respect to that due to the flow of ground water.

The organic compounds observed in the Upper Zone Aquifer in the Flightline Area are volatile by nature, and any volatilization of these compounds from the ground-water system could result in their permanent removal. Although some of the compounds might be adsorbed onto overlying sediments, historically the Upper Zone Aquifer water table has not changed significantly, and therefore there is little chance of the compounds being resorbed back into the ground-water system.

Tetrachloroethene, trichloroethene, cis- and trans-1,2-dichloroethene and vinyl chloride are all chlorinated solvents and related by the chemical process of hydrogenolysis (Figure 5-1). This process is very common in nature and may be biologically driven, as a form of biodegradation. Based on available records and water sampling results, it appears TCE was the principal solvent disposed of in the Flightline Area, and the cis- and trans-1,2-DCE and vinyl chloride detected in lesser quantities are mainly daughter products of the TCE (and possibly the PCE).

Transport in Ground Water

Using data obtained from the June 1990 Upper Zone Aquifer pumping test and the potentiometric surface map of the aquifer, the average ground-water flow rate in the Upper Zone is calculated to be approximately 9 feet per day. By comparing the TCE contaminant plume position as determined in both 1988 and 1990, it appears the plume is migrating approximately an order of magnitude slower than the ground water. The contaminant plume migration does not conform wholly to the ground-water flow direction, which is generally toward Farmers Branch. A portion of the plume appears to be preferentially moving through the thickest accumulations of sand and gravel in the Upper Zone, in a more easterly direction than the shallow ground-water flow. While Farmers Branch and one of its tributaries are capturing a portion of the contaminant plume, there is continued plume migration in a generally east-south-easterly direction from the Flightline Area.

Transport in Surface Water

The two main surface water bodies in the study area, Farmers Branch and the small tributary to Farmers Branch, were found to contain varying concentrations of volatile organic compounds. The small tributary exhibited the greatest degree of contamination, the indirect source of which is believed to be discharge of Upper Zone ground water. A portion of Farmers Branch that is upstream of, and therefore unaffected by the Flightline Area sites, contained volatile organic compounds from an upstream source. Currently, the estimated concentration of TCE migrating off-site in Farmers Branch is 45 μg/L, and 1,2-DCE is estimated at 8 μg/L. Volatilization will reduce the volatile organic contaminant content of Farmers Branch before its ultimate discharge into the Trinity River.

7.1.3 Risk Assessment

Using both the 1988 and 1990 analytical results from soil, ground water, and surface water samples collected in the Flightline Area, 19 indicator chemicals were selected from the approximately 80 chemicals known to be present at the site. The indicator chemicals consisted of 10 metals, eight volatile organic compounds and one semivolatile organic compound. These chemicals were selected according to the methods in the U.S. EPA Health Evaluation Manual (1986a). Although several of the indicator chemicals selected, particularly the metals and the semivolatile compound, are not believed to represent an actual contaminant problem at the site, they were included in the risk assessment process to ensure a conservative evaluation of possible health risks.

Possible mechanisms of contaminant release from the Flightline Area sites include: 1) volatilization to the air, 2) fugitive dust generation, 3) leachate to ground water, 4) surface runoff, 5) direct release to surface water, and 6) contaminated ground-water discharge to surface water. Of these six possible mechanisms, volatilization to the air, leachate to ground water, and contaminated ground water discharging to surface water appear to be the most important release mechanisms in the Flightline Area.

Potentially significant contaminant transport and fate mechanisms were identified and include: 1) air dispersion, 2) ground-water migration, 3) discharge to the surface, 4) transport in surface water, and 5) subsequent uptake by plants and animals.

Results of an evaluation to determine possible human exposure routes from the six previously mentioned waste release mechanisms (Figure 6-1) show six potential pathways exist. All six of the pathways initially involve contaminants volatilizing to the air or leaching to the ground water. Based on the potential pathways identified, potential human and wildlife receptors for exposure to contaminants migrating from the Flightline Area were identified.

Three types of exposures - inhalation, ingestion, and dermal contact were quantified in the risk assessment. The maximum predicted annual average concentrations resulting from estimated Flightline Area VOC indicator chemical emissions are lower than the conservative TACB Effects Screening Levels by orders of magnitude ranging from 4 to 8. Potential ingestion exposures included consuming meat and dairy products or fish exposed to contaminants, however, neither of these potential pathways were found to represent a significant threat of human exposure. Dermal exposure to contaminants in Lake Worth and the Trinity River was found to be insignificant, at most. Skin contact with water in Farmers Branch, which is not amenable to swimming or contact activities other than wading, could result in dermal exposure, but the insignificance of such potential exposure did not merit quantification.

The threat to human health posed by the site was evaluated in terms of noncarcinogenic and carcinogenic risks. The noncarcinogenic evaluation involved comparing maximum predicted annual average volatile organic contaminant concentrations at various locations, both on-site and off-site, with inhalation Reference Doses (RFDs) for chronic (long-term) exposure. The results of this comparison indicate the threat of noncarcinogenic health effects of inhalation exposure to contaminants released from the Flightline Area is not significant. Concerning carcinogenic risks, seven of the eight VOC indicator chemicals are potential carcinogens. Incremental individual cancer risks were estimated for maximum exposed individuals at locations both on- and off-site. The highest risk of one in 10 million was dismissed as inconsequential. Ingestion and dermal risks were considered minimal and were not quantified.

When considering the threat to wildlife and aquatic organisms from the contaminants migrating from the Flightline Area, the level of contaminants found in the site surface water bodies were compared to the EPA <u>Quality Criteria for Water</u> (1986b). Some risk exists for terrestrial wildlife that use Farmers Branch, the small tributary, or the golf course ponds as a source of drinking water, as well as for aquatic organisms in these surface water bodies. Lead was detected in a concentration exceeding the chronic criterion for fresh water aquatic life in the westernmost golf course pond (Figure 5-9), however the reported result is questionable because it was from the dissolved lead analysis, and the total lead concentration in the unfiltered sample was less than the chronic criterion. Silver was detected at three locations in concentrations above the chronic criterion, but all three results were for total silver. Silver was not detected in the dissolved phase, however, the detection limit for the analytical method (10 $\mu g/L$) was greater than the chronic criterion. Therefore it is not possible to determine whether any dissolved silver concentrations exceeded the criterion.

7.2 Conclusions

The following subsections focus on additional data requirements, recommended ways to obtain the additional data, and the remedial action objectives for the Flightline Area.

7.2.1 Data Limitations and Recommendations for Future Work

The remaining information needed from the Flightline Area is primarily for more complete definition of the extent of the volatile organic contaminant plume, and better understanding of the mechanics of ground-water flow in the Upper Zone. Specifically:

- The lateral and downgradient limits of the VOC plume in the Upper Zone Aquifer;

- Identification and characterization of the upgradient, off-base source(s) of Upper Zone contamination in the Flightline Area;

- The VOC content of the water in Farmers Branch at a location immediately upstream of its discharge point to the Trinity River;

- Computer modelling of ground-water flow and contaminant transport;

- Upper Zone Aquifer properties, such as transmissivity and storage coefficient, near Farmers Branch and the small tributary.

Although estimates of aquifer properties were obtained as a result of the June 1990 pumping test, this test was conducted in an area where the thickest sequence of sands and gravels observed in the Flightline Area occurs. If, as anticipated, the selected remedial alternative involves the use of ground-water extraction wells in areas with thinner, less permeable Upper Zone sediments, the aquifer properties in these areas will require re-evaluation. Also, various scenarios of the aquifer response to pumping can be generated with computer programs.

Specific recommendations for additional work in the Flightline Area follow. All of these activities could be incorporated into the detailed design phase for the selected remedial alternative.

1) Installing up to five additional Upper Zone monitor wells to determine the lateral and downgradient extent of the VOC contaminant plume. The location of the wells will be selected to determine the downgradient (easternmost) extent of the plume, and to determine whether the contaminant plume extends beneath Farmers Branch to the north. These wells could also be included in any long-term monitoring scheme to evaluate the effectiveness of the selected remedial alternative in preventing further plume migration.

2) Performing one round of ground-water sampling and analyses for volatile halocarbon compounds that includes all Carswell AFB Flightline monitor wells, and monitor wells previously installed by Hargis and Associates for AF Plant 4 in the Carswell Flightline Area and on adjoining AF Plant 4 property.

Analytical results from this effort would help to determine the location, nature, and magnitude of upgradient contaminant sources; define the upgradient limits of Upper Zone ground-water contamination; and evaluate the degree of continuity of ground-water contamination beneath AF Plant 4 and the Carswell AFB Flightline Area.

3) Surface water sampling of Farmers Branch at a point just above its confluence with the Trinity River. Information gained through this activity will help in determining the extent of surface water contamination, will provide information regarding contaminant fate and transport, and will validate assumptions made in the risk assessment.

4) One to two aquifer tests along Farmers Branch and the small tributary are recommended to provide additional information to support remedial actions.

5) Computer modelling to obtain a better understanding of ground-water flow and contaminant migration patterns.

7.2.2 Recommended Remedial Action Objectives

The Flightline Area Upper Zone ground water, surface water, and soils are contaminated with volatile organic compounds. Based on the existing environmental conditions, the recommended objectives of any remedial actions are to:

1) Reduce or eliminate potential impacts to human health and the environment;

2) Reduce or eliminate the potential for future contaminant migration in the ground water or surface water; and

3) Reduce, eliminate, or immobilize contaminants in near-surface soil (Upper Zone deposits).

To identify and evaluate remedial alternatives, potentially contaminated environmental media were identified based on previous Flightline Area investigative results. These media include waste material and contaminated soil, Upper Zone ground water, and surface water. Specific remedial action objectives identified for each of the media are presented in Table 7-1. Remedial action objectives were developed for each media based upon the following standards or criteria:

- 70-year cancer risk potential;

- National interim primary drinking water standards maximum contaminant levels (MCLs) for organics (40 CFR 141.12 and 141.61) and inorganics (40 CFR 141.11 and 141.62); and

- Final MCLs for organics and inorganics (Federal Register, Vol. 56, No. 20, January 30, 1991.

Table 7-1 does not list all contaminants that have regulatory criteria or standards. Instead the table lists those contaminants that were identified as indicator chemicals in the baseline risk assessment for the Flightline Area. As previously explained, metals are included as indicator chemicals on the basis of total concentrations detected. However, the dissolved metals concentrations detected in the 1990 sampling event do not suggest a metals contamination problem.

TABLE 7-1. REMEDIAL ACTION OBJECTIVES FOR FLIGHTLINE AREA IRP SITES, CARSWELL AFB, TEXAS

Environmental Media	Remedial Action Objectives
WASTE AND CONTAMINATED SOIL	FOR HUMAN HEALTH: Prevent ingestion or direct contact with soil or waste at sites which contributes to greater than or equal to 10^{-6} excess cancer risk (or a potential risk characterized as greater than negligible) from the following carcinogens: TCE, benzene, bis(2-ethylhexyl)phthalate, arsenic, cadmium, and methylene chloride.
	Reduce inhalation of potential carcinogens [TCE, 1,2-DCE, tetrachloroethylene, vinyl chloride, methylene chloride, benzene, chloroform, and bis(2-ethylhexyl)phthalate] at locations which contribute to excess inhalation cancer risk levels of greater than or equal to 10^{-6} so that risk levels are lower than 10^{-6}.
	FOR ENVIRONMENTAL PROTECTION: Prevent migration of contaminants from soil that would result in ground-water contamination in excess of the following concentrations for each specific contaminant:

Inorganics		Organics	
Arsenic	0.05 mg/L	TCE	5 µg/L
Barium	1.0 (2.0) mg/L	Vinyl Chloride	2 µg/L
Cadmium	0.01 (0.005) mg/L	Benzene	5 µg/L
Chromium	0.05 (0.1) mg/L	cis-1,2-DCE	(100) µg/L
Lead	0.05 mg/L	trans-1,2-DCE	(70) µg/L
Selenium	0.01 (0.05) mg/L	Tetrachloroethene	8 µg/L
Silver	0.05 mg/L	Toluene	2,000 µg/L

(Continued)

( ) - Final MCL as of 30 January 1991, not effective until 30 July 1992.

TABLE 7-1. (Continued)

Environmental Media	Remedial Action Objectives
GROUND WATER	FOR HUMAN HEALTH: Prevent ingestion of ground water that contributes to an excess cancer risk of greater than or equal to 10^{-6}. FOR ENVIRONMENTAL PROTECTION: Remove contaminants from the ground water to levels below the following concentrations: **Inorganics** Arsenic . . . . 0.05 mg/L Barium . . . . 1.0 (2.0) mg/L Cadmium . . 0.01 (0.005) mg/L Chromium . . 0.05 (0.1) mg/L Lead . . . . 0.05 mg/L Selenium . . 0.01 (0.05) mg/L Silver . . . . 0.05 mg/L **Organics** Vinyl Chloride . . . . 2 µg/L Benzene . . . . 5 µg/L cis-1,2-DCE . . . . . . (100) µg/L trans-1,2-DCE . . . (70) µg/L TCE . . . . 5 µg/L Tetrachloroethene . . . 8 µg/L Toluene . . . . 2,000 µg/L
SURFACE WATER	FOR HUMAN HEALTH: Prevent ingestion of or skin contact with surface water that contributes to an excess cancer risk of greater than or equal to 10^{-6}. Prevent ingestion of fish from surface water that contributes to an excess cancer risk of greater than or equal to 10^{-6}. FOR ENVIRONMENTAL PROTECTION: Prevent future discharge of contaminated ground water to surface water. If treated ground-water effluent is discharged to Farmers Branch, it must meet the environmental protection criteria for ground water (above).

( ) = Final MCL as of 30 January 1991, not effective until 30 July 1992.

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GLOSSARY OF DEFINITIONS, NOMENCLATURE, AND UNITS

AA	atomic absorption
AFB	Air Force Base
Alluvium	stream-deposited sediment; predominantly clay, silt, sand, and gravel
Aquifer	geologic unit capable of storing and transmitting significant quantities of ground water
Aquitard	geologic unit impervious to ground water which acts to contain ground water within an adjacent unit
ARAR	Applicable or Relevant and Appropriate Requirement
Artesian	term applied to ground water confined under hydrostatic pressure
BLS	below land surface
DOD	U.S. Department of Defense
ECD	electron capture detector
EICP	Extracted Ion Current Profile
EPA	U.S. Environmental Protection Agency
Evapotranspiration	loss of water from the soil both by evaporation and by transpiration to growing plants
Extraction	method for mobilizing contaminant species from a solid matrix prior to analysis
FDTA	Fire Department Training Area
FS	feasibility study
GC	gas chromatography
GC/HSD	gas chromatography/halide specific detector
GC/MS	gas chromatography/mass spectroscopy
GFAA	graphite furnace atomic absorption spectroscopy

GLOSSARY OF DEFINITIONS, NOMENCLATURE, AND UNITS (Cont.)

gpd	gallons per day
gpm	gallons per minute
Hydraulic Conductivity	a coefficient of proportionality describing the rate at which water can move through a permeable medium
IRP	Installation Restoration Program
MCL	Maximum Contaminant Level
MS	mass spectroscopy
MSL	mean sea level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NCP	National Contingency Plan
OEHL	Occupational and Environmental Health Laboratory
OVA	organic vapor analyzer
O&G	oil and grease
PCB	polychlorinated biphenyl
PID	photoionization detector
piezometric/potentiometric surface	an imaginary surface representing the static head of ground water defined by the level to which water will rise in a well
PMCL	proposed maximum contaminant level
ppb	parts per billion
ppm	parts per million
QAPP	Quality Assurance Program Plan
QA/QC	Quality Assurance/Quality Control
RI/FS	Remedial Investigation/Feasibility Study
SOW	State of Work

GLOSSARY OF DEFINITIONS, NOMENCLATURE, AND UNITS (Cont.)

spike	a known amount of a compound added to a sample and analyzed to determine the accuracy of analysis
SW-846	EPA test methods for evaluating solid wastes, physical and chemical methods
TCE	trichloroethene
TDS	Total Dissolved Solids
TOC	Total organic carbon
TOX	Total organic halides
TPM	Technical Program Manager
Transmissivity	the rate at which water is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient.
USAF	United States Air Force
USAFOEHL	United States Air Force Occupational and Environmental Health Laboratory
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VOC	volatile organic compound
water table	the elevation of the ground water surface in an unconfined aquifer

GLOSSARY OF DEFINITIONS, NOMENCLATURE, AND UNITS (Cont.)

Multiplication Factor	Prefix	Symbol
$1{,}000{,}000{,}000{,}000{,}000{,}000 - 10^{18}$	exa-	E
$1{,}000{,}000{,}000{,}000{,}000 - 10^{15}$	peta-	P
$1{,}000{,}000{,}000{,}000 - 10^{12}$	tera-	T
$1{,}000{,}000{,}000 - 10^{9}$	giga-	G
$1{,}000{,}000 - 10^{6}$	mega-	M
$1{,}000 - 10^{3}$	kilo-	k
$100 - 10^{2}$	hecto-	h
$10 - 10^{1}$	deka-	da
$0.1 - 10^{-1}$	deci-	d
$0.01 - 10^{-2}$	centi-	c
$0.001 - 10^{-3}$	milli-	a
$0.000\ 001 - 10^{-6}$	micro-	u
$0.000\ 000\ 001 - 10^{-9}$	nano-	n
$0.000\ 000\ 000\ 001 - 10^{-12}$	pico-	p
$0.000\ 000\ 000\ 000\ 001 - 10^{-15}$	fento-	f
$0.000\ 000\ 000\ 000\ 000\ 001 - 10^{-18}$	atto-	a

ppm(parts per million) - mg/kg, ug/g, ng/mg, pg/ug, mg/L, ug/mL, ng/uL
ppb (parts per billion) - ug/kg, ng/g, pg/mg, ug/L, ng/mL, pg/uL
ppt (parts per trillion) - ng/kg, pg/g, fg/mg, ng/L, pg/mL, fg/uL

APPENDIX A

Lithologic Logs

(Previous Lithologic Logs may be found in CH2M Hill (1984), Radian (1986), and Radian (1989))

DRILLING LOG | RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX | SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 40.1 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 17
4. HOLE NO.: LF04-01	11. ELEVATION GROUND WATER: 600.26 ft MSL (6/18/90)
5. NAME OF GEOLOGIST: S. E. Fain	12. DATE HOLE ESTABLISHED: 3/23/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 626.50 ft MSL
X: 2019579.19 Y: 397653.57	14. BACKGROUND:
	15. MEASURING POINT ELEVATION: 629.24 ft MSL

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Dark brown, slightly silty, very stiff, damp minor small gravel.	Full recoveries unless noted.
2			U/CLLR	Clay: As above, 5 - 10% calcareous material (nodules, mottling).	
4			U/CLLR	Clay: Orange/Brown, silty, minor fine sand, calcareous material ~ 10 - 20% of sample, very stiff.	Could not cut with knife.
6			U/CLLR	Clay: As above, mottling of various colors is disturbed looking.	
8			U/CLLR	Clay: As above, ~ 20% green silty clay.	Boring does not appear to encounter fill material (Like LF05-02).
10			U/CLLR	Clay: Orange/brown with greenish mottling, silty, sandy, ~ 1% calcareous material, firm.	
12.3			U/SDSM	Sand: Orange/brown, very clayey and silty; very fine to fine grained, bedding (horizontal) evident, damp: Clays occur mainly in 2 - 4 in. seams ~ every foot.	
14			U/SDSM	Sand: As above.	
16			U/SDSM	Sand: Burnt orange, fine grained, slightly clayey, damp, quartzose, Clay occurs as thin seams.	1.2 ft. Recovery
19			U/SDFN	Sand: Tan, fine grained, loose, >95% quartz, damp; oxidation stained laminae 21.5 - 22 ft.; 0.4 ft. clay seam 21.1 - 21.5 ft.	4.2 ft Recovery.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 40.1 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 17	
4. HOLE NO.: LF04-01		11. ELEVATION GROUND WATER: 600.26 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/23/90	
6. COORDINATES OF HOLE: X: 2019579.19 Y: 397653.57		13. SURFACE ELEVATION: 626.50 ft MSL	
		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 629.24 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
24			U/SDFN	Sand: As above, heavily oxidized 24 - 25 ft.	
25			U/CLLR	Clay: Brown, gray in 1 - 2 in. seams, oxidation mottling, sandy (fine grained), cohesive, moist; getting sandier past 28 ft., wet at 28.5 ft.	
29			U/CLLR	Clay: Brown, very sandy, saturated, slightly cohesive; sand is very fine to fine grained, ~ 30 - 40%; 31 - 32 ft. clay, little sand; 32 - 34 ft. sand with minor clay.	W. L. Measured down augers at 29.6 ft. BLS, W. L. after completion = 27.5 BLS, 3.6 ft. Recovery.
32			U/SDSM	Sand: Burnt orange (heavily oxidized), fine to medium grained, slightly clayey, slightly cohesive. Increasing coarseness and 10 - 20% gravels (small) 33 - 34 ft.	
34			U/SDGR	Sand and Gravel: Orange, 50/50, wet; sands very fine to very coarse grained, poorly sorted; gravels bimodal: chert and quartz gravels, mostly granule and small pebble size; large gravel (20 - 50 mm) is very fossiliferous limestone clasts.	3.0 recovery at 36 ft.
39			U/SDGR	Sand and Gravel: As above, numerous shell fragments	Sampler Refusal at 40.0 ft.
40		50	U/MARL	Marl: Limestone, weathered, chalky, fissile.	Drove 1 1/2 in. 5.5 ft. sampler; 50 blows = 1 in.; T.D. = 40.1.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 37.7 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 14	
4. HOLE NO.: LF04-02		11. ELEVATION GROUND WATER: 597.45 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/28/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 621.00 ft MSL	
X: 2020510.50 Y: 397732.54		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 623.68 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Dark brown, silty, firm, roots, damp, carbonaceous staining.	Full samplers unles noted.
2			U/CLLR	Clay: As above; at 3.0 ft. going to orange/brown, silty clay with 5 - 10% calcareous material.	
4			U/CLLR	Clay: As above.	1.5 ft. Recovery
6			U/CLLR	Clay: Orange/brown, very silty, minor very fine grained sand, stiff, calcareous nodules, carboaceous streaking.	
8			U/CLLR	Clay: As above, increasing calcareous material to 30%.	
11			U/SDGR	Sand and Gravel: Orange, very poorly sorted, cohesive, clayey, silty, damp, abundant calcareous material.	
13			U/SDLR	Sand: Orange, fine grained, minor larger sizes to coarse, slightly clayey and silty, damp.	
13.5			U/SDLR	Sand: As above, increasing coarseness with depth, 5 - 10% small gravels.	
16.5			U/SDLR	Sand: As above, gravelly; changing to tan, fine to medium grained, loose, quartzose at 18.0 ft., damp.	
18.5			U/SDLR	Sand: As above, well sorted, medium grained, damp; 0.4 ft gravelly zone at 21.5 - 21.9 ft.	3.5 ft. Recovery

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 37.7 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 14	
4. HOLE NO.: LF04-02		11. ELEVATION GROUND WATER: 597.45 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/28/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 621.00 ft MSL	
X: 2020510.50 Y: 397732.54		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 623.68 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
23.5			U/SDLR	Sand: Orange/tan, medium grained, well sorted, subround, >90% quartz; 0.3 ft. gravelly zone at 27 ft., saturated at 28 ft.	4.0 ft. Recovery
28.5			U/SDLR	Sand: As above, 1-3% granule size gravel.	W. L. measured at 28.1 ft. BLS, 5.0 ft. Recovery
33.5			U/SDLR	Sand: Tan, medium grained, quartzose, loose, wet, 5% gravels to 25 mm.	3.7 ft. Recovery.
37			U/MARL	Limestone: Marly, weathered sand and gravel intermixed, fissile.	T.D. = 37.7 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 37.6 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 14	
4. HOLE NO.: LF04-03		11. ELEVATION GROUND WATER: 597.58 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. B. Blount, S. E. Fain		12. DATE HOLE ESTABLISHED: 3/20/90	
6. COORDINATES OF HOLE: X: 2020506.79 Y: 397683.46		13. SURFACE ELEVATION: 620.50 ft MSL	
		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 623.25 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLAY	Clay: Brown, soft to firm, semi-plastic, with fine rootlets and minor carbonaceous streaking and particles, moist to wet.	Full recovery unless otherwise indicated.
2			U/CLAY	Clay: As above, firm to stiff (stiffens to base), minor calcareous debris, more abundant carbonaceous staining, very stiff; 3.8 - 4.0 ft.	Too stiff to cut.
4			U/CLLR	Clay: Orange/brown at 4.1 ft; brittle, damp, abundant calcareous debris, slickensided, calichified with some authigenic mineralization (crystals of CaCO3 in shell frags.); very hard, silty.	Hard pushing.
6			U/CLLR	Clay: As above, very stiff, slightly sandy and silty.	
8			U/CLLR	Clay: As above, few large CaCO3 pebbles (25 mm), increasing clacareous material with depth, very fine grained sand.	1 ft. recovery, ST. Rig broken. Continue after repairs.
10			U/CLLR	Clay: Orange/brown, silty, cohesive, damp, > 30% calcareous material, stiff.	Caliche layer at 12 ft., drilling through.
12.1			U/SDFN	Sand: Orange, fine grained, loose, damp, quartzose, well sorted; at 14.3 ft. sharp change to tan, very fine grained sand, heavily oxidized in laminae.	
14.5			U/SAND	Sand: Orange, fine to medium grained, quartzose, damp, loose; gravelly seam 15 - 15.5 ft.	3 ft. Recovery.
19.5			U/SDLR	Sand: Orange/tan, fine to medium grained, damp, loose, subround, > 90% quartz, 1 - 3% small gravel and shells.	4 ft. Recovery.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 37.6 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 14	
4. HOLE NO.: LF04-03		11. ELEVATION GROUND WATER: 597.58 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. B. Blount, S. E. Fain		12. DATE HOLE ESTABLISHED: 3/20/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 620.50 ft MSL	
X: 2020506.79 Y: 397683.46		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 623.25 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
24.5			U/SDLR	Sand: Orange/tan, fine to medium grained, wet, loose, 0.5 ft. gravelly zone at 27 ft., quartzose; at 30 ft.	W. L. measured at 26.3 ft. Bls. 2.6 ft. recovery.
29.5			U/SDLR	Sand: As above, saturated.	3.2 ft. Recovery.
32			U/GRVL	Gravel: Varicolored, up to pebble size (30 mm), shells, <10% sand, saturated.	
34.5			U/GRVL	Gravel: As above, mainly small pebble size (5 - 10 mm), shells, subangular to subrounded, large percentage of chert.	
37.5		50	U/MARL	Marl: Chalky gray, indurated, oxidation stained throughout.	Sampler refusal at 37.5 ft., drove 1 1/2 in. S.S. 50 blows = 1 in.; T.D. = 37.6 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 25.4 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 10	
4. HOLE NO.: LF04-04		11. ELEVATION GROUND WATER: 595.32 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/20/90	
6. COORDINATES OF HOLE: X: 2021365.82 Y: 397554.53		13. SURFACE ELEVATION: 609.40 ft MSL	
		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 612.07 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Red/brown, sandy, silty, damp, cohesive, roots; increasing sand with depth.	Full sample recoveries unless noted.
1.5			U/SDSM	Sand: Red/brown, clayey, cohesive, minor small gravel, damp, decreasing clay content with depth.	1.6 ft. Recovery.
4			U/SAND	Sand: Orange, fine to medium grained, slightly cohesive, quartzose, damp, subangular to subrounded.	
6			U/SAND	Sand: As above, only tan and loose.	1.7 ft. Recovery.
8			U/SAND	Sand: As above, damp.	1.5 ft. Recovery.
10			U/SDLR	Sand: Tan with occassional iron stained thin beds, loose, damp, fine to medium grained; 1 - 3% gravels starting at 12.5 ft.	3.7 ft. Recovery.
13.7			U/SDGR	Sand and Gravel: Fine sand to pebble size gravel, slightly clayey, shells, 50/50 sand to gravel, mainly quartz/chert, wet.	3.5 ft. Recovery.
19			U/GRSM	Gravel and Sand: As above, but gravel content increasing to 70%, gravels mostly 5 - 10 mm; but some to 40 mm, sand mainly coarse grained, limestone clasts; 23 - 24 ft. slightly indurated - increased limestone content.	4.0 ft. Recovery.

DRILLING LOG | RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX | SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 25.4 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 10
4. HOLE NO.: LF04-04	11. ELEVATION GROUND WATER: 595.32 ft MSL (6/18/90)
5. NAME OF GEOLOGIST: S. E. Fain	12. DATE HOLE ESTABLISHED: 3/20/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 609.40 ft MSL
X: 2021365.82 Y: 397554.53	14. BACKGROUND:
	15. MEASURING POINT ELEVATION: 612.07 ft MSL

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
24			U/GRSM	Gravel and Sand: As above.	
25		50	U/MARL	Limestone: (Marl) White/gray with iron staining in fractures, indurated, shaley parting.	Sampler refusal at 25.0 ft., well drive 5.5 ft.; 50 blows = 4.0 in.; T.D. = 25.4 ft.

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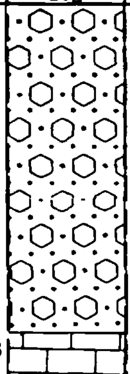
DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS

1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 26.1 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 12
4. HOLE NO.: LF04-05	11. ELEVATION GROUND WATER:
5. NAME OF GEOLOGIST: S. B. Blount	12. DATE HOLE ESTABLISHED: 3/28/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 608.80 ft MSL
X: 2020805.42 Y: 397347.91	14. BACKGROUND:
	15. MEASURING POINT ELEVATION:

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Dark brown grading to brown and orange mottled, fine roots, soft to firm, damp, silty with minor (< 5%) calcareous debris and carbonaceous streaking.	Full samplers unles noted otherwise.
2			U/CLLR	Clay: As above, calcareous debris in small caliche pockets (<5 mm).	1 ft. Recovery.
4			U/CLLR	Clay: As above, calcareous debris zone 4.6 - 4.9 ft., otherwise less than 5%; softer, moist.	1 ft. Recovery.
6			U/CLLR	Clay: As above, mottling decreased - uniform orange color; calcareous debris and rootlets < 2%; increased silt to almost clayey silt.	1.5 ft. Recovery.
8.8			U/SDSM	Sand: Tan/buff at 8.8 ft.; very fine to fine grained, moderate to poor sorting, subangular, quartzose with > 95% quartz and heavy minerals, very loose, damp, minor clay lenses at top, few coarse shell fragments.	1.5 ft. Recovery, Very sharp contact, sample disturbed (in pile).
11.1			U/SDGR	Sand and Gravel: at 11.1 ft. sand is as above, oxidized orange, wet, very poorly sorted; gravel is ~ 30%, average 10 mm, CaCO3, minor clay makes entire sample fairly cohesive; Clay increases to 13 ft.	1 ft. Recovery.
12			U/GRSM	Gravel, Sand, and Clay: As above, gravel up 40%.	Water in hole at 12 ft.; W. L. = 12.72 ft., 13 to 14 ft. no recovery.
14			U/GRSM	Gravel and Sand: As above, with minor clay.	
16			U/GRSM	Gravel and Sand: Orange, 60% + gravel, average 20 mm up to 80 mm; very poor sorting, subrounded; coarse fraction predominantly CaCO3 frags; finer fraction predominantly variclored subrounded quartz grains; some small shell frags (sand sized), very loose; wet.	Poor recovery; gravel slipped out.
19			U/GRSM	Gravel and Sand: As above, gravel is 'coarse' as above - average 20 mm; sand is fine to coarse grained, quartzose, loose, wet, very porly sorted, subangular.	Possibly gravel only; sample poor; sand recovered may be sluff.

DRILLING LOG — RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX — SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 26.1 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 12
4. HOLE NO.: LF04-05	11. ELEVATION GROUND WATER:
5. NAME OF GEOLOGIST: S. B. Blount	12. DATE HOLE ESTABLISHED: 3/28/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 608.80 ft MSL
X: 2020805.42 Y: 397347.91	14. BACKGROUND:
	15. MEASURING POINT ELEVATION:



Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
24			U/GRSM	Gravel and Sand: As above, good coarsening downward seq., fine to medium grained sand to sand and gravel to clean fine gravel to coarse gravel; sand is same as 11 to 12 ft.	
25.8		50	U/MARL	Marl: Highly calcareous, fissile, semi-indurated, shaley clay; light to medium grey, heavily oxidized between lamina, harder to base (clay-like at top), brittle, wet.	Refused at 26 ft. Went in with SS; 50 blows went < 0.1 ft. Abundant coarse gravel on augers when removed. T.D. at 26.1 ft.. Hole caved to 14.5 ft. after auger removal.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 31.5 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 13	
4. HOLE NO.: LF04-06		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/28/90	
6. COORDINATES OF HOLE: X: 2020593.25 Y: 397210.60		13. SURFACE ELEVATION: 613.30 ft MSL	
		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Brown, soft to firm, semi-plastic, sandy in intervals (1 - 1.5 ft.), roots, moist, minor calcareous flecks.	Full recovery unless noted otherwise. 1 ft. Recovery.
2			U/CLLR	Clay: As above.	
3.3			U/CLLR	Clay: Brown, firm semi-brittle, abundant calcareous debris, dry to damp, minor roots, caliche zone to 5.4 ft.; caliche is dry, white/brown mottled, brittle, sandy with calcareous and carbonareous debris.	
5.4			U/SAND	Sand: Orange, very fine grained, subrounded, moderately sorted, quartzose w/ < 95% quartz, dry, loose w/ minor rootlets, few shell fragments < 3 mm.	Sharp contact.
8			U/SDLR	Sand: As above, clayey soil horizion at top with pebbles (calcareous), roots.	Musky odor.
10		9,17,17	U/SDLR	Sand: As above, thin pebble layer at 10.2 - 10.5 ft. (pebbles calcareous and up to 15 mm); sand below very fine grained with some coarser fraction, poorly sorted, few calcareous pebbles < 10 mm, minor shell frags, single gravel clast - 25 mm.	ST refusal at 12 ft.; drive SS.
14			U/SDLR	Sand: As above.	
16			U/SDLR	Sand: Yellow-orange, very fine grained, subangular, moderately well sorted, quartzose > 95% quartz, loose, moist to 17.5 ft., moist to wet to 19 ft., wet below; minor gravel < 1% throughout; color laminations/mottling, coarsening downward.	
20			U/SDLR	Sand: Light brown/tan, very fine to medium grained, very poorly sorted, angular, quartzose with 5 - 10% heavy minerals, loose, saturated, rock fragments (very coarse sand/fine pebbles) increase to base ~ 25% from	Water in hole at 20 ft. Sand and gravel.

DRILLING LOG | RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX | SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 31.5 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 13
4. HOLE NO.: LF04-06	11. ELEVATION GROUND WATER:
5. NAME OF GEOLOGIST: S. B. Blount	12. DATE HOLE ESTABLISHED: 3/28/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 613.30 ft MSL
X: 2020593.25 Y: 397210.60	14. BACKGROUND:
	15. MEASURING POINT ELEVATION:

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
				23 - 24.1 ft.; sand at base, few large cobbles.	
25			U/SDLR	Sand: As above.	
26.2			U/GRSM	Gravel and Sand: Gravel is very poorly sorted from 2 to 30 mm, composed of quartz, calcareous lithoclasts and shell fragments. Sand is as above.	
29.6			U/GRSM	Gravel, Sand, and Clay: Highly calcareous, chalky, soft.	Mild HC odor at bottom of sample.
31			U/MARL	Marl: Fissile, indurated, light grey, calcareous, brittle, shaley. (Minor marly frags at bottom of sample = basis for description)	Refused at 31 ft. Could not sample with SS. Cave in. Will enter with bit and obtain solid bit refusal. Entire recovery fell; Driller says bit refusal at 31.5 ft. T.D. at 31.5 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 39.1 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 15	
4. HOLE NO.: LF04-07		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 630.40 ft MSL	
X: 2020897.22 Y: 396819.74		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Dark Brown, silty, firm to stiff, damp, roots; calcareous nodules abundant 3 - 4 ft., carbonaceous streaks.	Full sample recoveries unless noted. 1 ft. Recovery.
4			U/CLLR	Clay: As above, Orange/Brown, getting siltier, stiff.	
6.5			U/SILT	Silt: Orange/Brown with very fine sand, dry, cohesive, abundant calcareous nodules and infilled fissures, carbonaceous staining in laminae.	
9.8			U/SDVF	Sand: Tan, very fine grained, loose, dry, well sorted.	Pushed 1.5 ft. SS. sampler.
10			U/SDVF	Sand: As above, dry.	1.5 ft. Recovery.
15			U/SDVF	Sand: As above, slightly indurated in places.	2.5 ft. Recovery.
18			U/SAND	Sand: Orange/Tan, very fine grained to fine grained slightly indurated in places, trough cross-laminated, oxidation staining in laminae.	
20			U/SAND	Sand: As above, dry.	3.0 ft. Recovery

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 39.1 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 15	
4. HOLE NO.: LF04-07		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 630.40 ft MSL	
X: 2020897.22 Y: 396819.74		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
23.7			U/SDGR	Sand and Gravel: Tan, 50/50, gravel is mainly granule size (chert and shell fragments), loose, dry, subrounded.	
25			U/SDGR	Sand and Gravel: As above, dry, poorly sorted, very fine sand to pebble size gravel (10 mm).	2.7 Recovery.
28			U/SDVF	Sand: Orange, slightly clayey (28 - 29 ft.), damp, very fine grained.	
30			U/SDFN	Sand: Orange/Tan, fine grained, loose, slightly damp, well sorted, quartzose.	2.3 ft. Recovery.
33			U/SDFN	Sand: As above.	
35			U/SDLR	Sand: Orange/tan, damp, fine to medium grained, loose; 1 - 3% small gravel 37 - 38.2 ft., wet, medium to coarse grained.	W. L. measured at 37.0 ft., 2.5 ft. Recovery, Auger refusal at 38.5 ft.
38.2		50	U/MARL	Marl: Whitish - Gray with oxidation staining, calcareous, indurated.	Drove 15 in. S.S.; 50 blows/ 3/4 in.; 38.6 ft. T.D.

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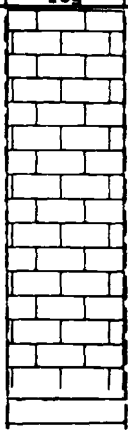
DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 3 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 47.4 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 17	
4. HOLE NO.: LF04-08		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 630.00 ft MSL	
X: 2020021.91 Y: 396935.08		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLAY	Clay: Dark Brown, stiff, damp, roots, calcareous nodules at 3.5 - 4.0 ft.	Full sample recoveries unless noted.
2			U/CLLR	Clay: As above, silty.	
5			U/SILT	Silt: Orange, sandy (very fine grained), dry, cohesive, carbonaceous spotting.	No Recovery; could not get sample out of shelby tube, Description based on top and bottom of sample.
8.1			U/SDFN	Sand: Orange/tan, fine grained, loose, dry, well sorted, subround, quartzose.	
10			U/SDFN	Sand: As above, horizontal bedding seen in/as minor color changes, dry; going to tan at 12 ft.	
14			U/SDFN	Sand: As above.	Started with 5 ft. sampler at 14 ft., 3 ft. Recovery.
17			U/SAND	Sand: Tan, very fine to fine grained, dry to slightly damp, > 95% quartz, subangular to subround, frosted.	
19			U/SAND	Sand: As above, still dry, mainly fine grained.	3.5 ft. Recovery.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 3 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 47.4 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 17	
4. HOLE NO.: LF04-08		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE: X: 2020021.91 Y: 396935.08		13. SURFACE ELEVATION: 630.00 ft MSL	
		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
24			U/SAND	Sand: As above.	
25.2			U/SDLR	Sand: Gravelly, very fine sand to pebble size (20 mm) gravel, dry to slightly damp, gravel mostly chert, 0.1 ft. white fossilferous limestone bed at 28 ft. Tan fine sand 28.1 ft. to 29 ft.; gravels ~ 5% - 10%.	3.2 ft. Recovery
29			U/SDLR	Sand: Tan, fine to medium grained, loose, dry, quartzose, 1 - 3% chert gravel.	4 ft. Recovery
33			U/SDLR	Sand: As above, increasing gravel to 5 - 10% at 33 - 34 ft.	
34			U/SDLR	Sand: As above, wet, fine to medium grained.	W. L. measured at 35.2 ft. BLS.. 1.5 ft. Recovery.
37			U/MARL	Marl: Gray, fossiliferous, weathered; intermixed with sand and gravel, wet, gravels are granule and pebble size, mainly chert.	Not good limestone or shale. Still significant sand and gravel.
39			U/MARL	Marl: Thin beds and gravel size pieces of limestone intermixed with sand, gravel, and shells, wet, shaley.	3.6 ft. Recovery.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 3 OF 3 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 47.4 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 17	
4. HOLE NO.: LF04-08		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE: X: 2020021.91 Y: 396935.08		13. SURFACE ELEVATION: 630.00 ft MSL	
		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	



Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
44			U/MARL	Marl: As above, indurated limestone beds (0.1 - 0.3 ft.) intermixed with gravelly sand.	Drilling through marl, looking for auger refusal.
47		50	U/SHLE	Shale: Dark Gray, indurated, fissile, no fossils, homogeneous.	Auger refusal at 47 ft.; 50 blows for 0.4 ft.; T.D. = 47.4 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 3 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 47.0 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 17	
4. HOLE NO.: LF04-09		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/6/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 627.40 ft MSL	
X: 2021145.70 Y: 397136.15		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Brown, going to red/brown at 2 ft., silty, moist; at 2.7 ft. dry, crumbly, very stiff, roots, minor carbonaceous staining.	Top soil first 1 ft.; Using 5 ft. S.S. sampler; 4 in. O.D., 3 1/2 in. I.D.
4			U/CLLR	Clay: Brown, silty, minor very fine grained sand, calcareous nodules 5 - 5.2 ft., carbonaceous staining in root areas, increasing very fine grained sand at 7.5 ft.	
8			U/CLLR	Clay: As above, Red and Brown mottled, dry.	
9.6			U/SAND	Sand: Orange, very fine to fine grained, quartzose, damp, loose.	3.5 ft. Recovery (9 - 12.5 ft.).
11.5			U/SDGR	Sand and Gravel: Orange/tan, poorly sorted, loose, damp, numerous shells, gravels to 20 mm.	
14			U/SAND	Sand: Light tan, very fine to medium grained, loose, dry, various mineralogies.	2.5 ft. Recovery.
16			U/SDGR	Sand and Gravel: Tan, very fine sand - pebble size gravel, loose, damp, numerous shells, various mineralogies.	
17			U/SDVF	Sand: Tan, very fine grained, quartzose, loose, dry, well sorted, subround, slightly indurated and laminated 18.5 - 19 ft.	
19			U/SDGR	Sand and Gravel: Orange/tan, poorly sorted, 50% sand - 50% gravel, numerous pelycepod? shells, loose, damp; 0.2 ft. brown clay seam at 22 ft.; gravels to 30 mm, subround.	3.5 Recovery.

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DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 3 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 47.0 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 17	
4. HOLE NO.: LF04-09		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/6/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 627.40 ft MSL	
X: 2021145.70 Y: 397136.15		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
25			U/SDLR	Sand: Tan, fine grained, > 90% quartz, dry, loose, well sorted, subangular to subrounded, minor small gravel.	3 ft. Recovery.
29			U/SDLR	Sand: As above, increasing gravel.	
30.5			U/MARL	Marl: Limestone thin beds (0.1 - 0.3 ft.) with gravel size material interlayered, semiconsolidated.	Still relatively easy drilling.
32			U/MARL	Marl: As above, damp, slightly consolidated, fissile in places, various gravel size particles.	Weathered limestone?
34			U/MARL	Marl: As above, numerous small shells, abundant chert gravel, wet; some gravels are subround.	Wet at 34 ft. (measured W.L. = 33 ft. 10 in.). Still easy drilling.
39			U/MARL	Marl: As above.	Quit sampling, drilling to determine depth to auger refusal.

DRILLING LOG | RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX | SHEET 3 OF 3 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 47.0 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 17
4. HOLE NO.: LF04-09	11. ELEVATION GROUND WATER:
5. NAME OF GEOLOGIST: S. E. Fain	12. DATE HOLE ESTABLISHED: 3/6/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 627.40 ft MSL
X: 2021145.70 Y: 397136.15	14. BACKGROUND:
	15. MEASURING POINT ELEVATION:

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
44			U/MARL	Marl: As above.	Descriptions based on returns and drilling speed. Auger refusal at 47 ft.. No drager tube detection (2/9) at top of auger.
47			U/MARL	Marl: As above.	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 3 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 49.1 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 18	
4. HOLE NO.: LF04-10		11. ELEVATION GROUND WATER: 596.05 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 4/2/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 626.90 ft MSL	
X: 2021275.03 Y: 397025.34		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 626.54 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Brown with orange mottling, soft to firm, damp, minor carbonaceous streaking, semi-plastic, silty seam, (parting) at 1 ft.. Coaly fragments. 0 to 0.05 ft.	Full recovery unless otherwise noted. Windy.
2			U/CLLR	Clay: As above, very silty to 3.2 ft., below 3.2 ft. has no silt, Orange/brown, plastic, firm, minor carbonaceous streaking.	'Contact' (fill material on top?).
4			U/CLLR	Clay: Very silty to 4.7 ft.. Same as 2 - 3.2 ft..	
4.7			U/CLAY	Clay: Burnt orange, firm to stiff, semi-plastic, damp with carbonaceous streaking, and minor calcareous debris; with calcareous debris concentrated from 5.6 - 5.8 ft.	Sharp 'contact'.
6			U/CLAY	Clay: As above, to 7.8 ft., calcareous debris, concentrated in 'caliche' layer 7.5 - 7.8 ft.	Hard pushing.
8			U/SAND	Sand: Very fine grained, moderately sorted, sub-rounded, Burnt Orange (oxidized), slightly silty in intervals (lenses); clay pocket (dark grey/soft) at 8.5 ft.; sand hav very minor carbonaceous streaks, damp, moist, at base; quartzose w/ < 95% quartz, < 5% iron magnesium.	Sharp contact, 1.5 Recovery (sand); sand is loose, cohesive w/ clay in lenses.
10			U/SDSM	Sand: As above, slightly silty to 11 ft., oxidation decreasing to base with color laminations evident. Clay lenses at 10 - 10.1 ft. and 10.6 - 10.7 ft.; sand is buff yellow at 11 ft..	1.5 ft. Recovery.
12			U/SDSM	Sand: As above, lighter color (buff tan), silty interval 13 - 13.3 ft., minor color laminae.	Pushed SS to 14 ft.; going to augers.
14			U/SDSM	Sand: As above, minor clayey lenses, semi-indurated sandstone layer at 14.9 - 15 ft.; damp, loose; with color laminae and < 5% heavy minerals.	2.5 ft. Recovery - MOSS.
19			U/SDSM	Sand: Very fine grained, buff w/ orange clay lenses, clay is moist, brittle, sandy, dark orange/brown, sand is moderately to poorly sorted, buff, grading to orange, silty from 19 - 19.5 ft. and 20.5 - 22.5 ft., dry to damp. No clay below 22.5 ft., very minor calcareous fragments.	4.5 ft. Recovery.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 3 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 49.1 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 18	
4. HOLE NO.: LF04-10		11. ELEVATION GROUND WATER: 596.05 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 4/2/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 626.90 ft MSL	
X: 2021275.03 Y: 397025.34		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 626.54 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
24			U/SDLR	Sand: As above, buff to orange laminated, no clay or silt, very fine grained, moderately well sorted, dry to damp; layer of abundant - 5% shell frags and calcareous debris with some gravel from 26 - 26.5 ft.; gravel up to 40 mm, minor gravel fragments to base.	3 ft. Recovery
29			U/SDLR	Sand: As above.	4.5 ft. Recovery.
30.5			U/SDGR	Sand and Gravel: Sand is very poorly sorted, buff, very fine to coarse grained, subrounded, with minor oxidation seams, gravel is 2 - 100 mm, approximatly 50%, composed of calcareous debris of shells etc. up to 5 mm; large fragments are broken, well indurated micritic limestone.	Sample wet at 32 ft..
33			U/SDLR	Sand: Tan, medium grained with abundant carbonaceous streaking and gravel, as above, at base.	Cobbles lengthwise in sampler.
34			U/GRSM	Sand and Gravel: Sand as above up to 15% gravel is quartz and calcareous debris, averaging 5 mm and up to 40 mm. Moderate to poor sorting, subrounded, wet. Large fragments are CaCO3, as above. Grain size increases to base.	
39			U/SDGR	Sand and Gravel: As above, wet, averaging 10 - 15 mm. Continues coarsening to base, minor clay pockets 40 - 42 ft. making fine gravel/slightly cohesive. Gravel up to 50 mm. Coarse Sand.	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 3 OF 3 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 49.1 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 18	
4. HOLE NO.: LF04-10		11. ELEVATION GROUND WATER: 596.05 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 4/2/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 626.90 ft MSL	
X: 2021275.03 Y: 397025.34		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 626.54 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
44.1			U/CLLR	Clay: 44.1 ft. clay is soft, very plastic, moist to wet, grey tan in color with abundant oxidation pockets (< 5 mm) around fine grained sand. Abundant carbonaceous flecks; silty below 46.5 ft. with silt layer 46.5 - 46.7 ft.	4.0 ft. Recovery. Sharp contact. Clay not 'sandy'; has few grains in each 'pocket'.
49			U/MARL	Marl: Clayey coated micritic limestone w/ recrystellized fossils, grey to buff, well indurated, 'mudstone'.	49 - 49.1 ft. augered into marl; 'core' sample. No SS. T.D. at 49.1 ft.

DRILLING LOG | RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX | SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 25.2 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 11
4. HOLE NO.: LF05-01	11. ELEVATION GROUND WATER: 603.82 ft MSL (6/18/90)
5. NAME OF GEOLOGIST: S. E. Fain	12. DATE HOLE ESTABLISHED: 3/22/90
6. COORDINATES OF HOLE: X: 2018791.38 Y: 399361.24	13. SURFACE ELEVATION: 619.30 ft MSL
	14. BACKGROUND:
	15. MEASURING POINT ELEVATION: 621.96 ft MSL

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Dark brown, firm, silty, red mottling, roots, damp; minor sand and gravel.	Fill.
2			U/SDLR	Sand: Tan, medium to coarse grained, loose, damp, ~ 5% small gravel.	
4			U/CLLR	Clay: As above, damp.	1.2 ft. Recovery.
8			U/CLLR	Clay: Brown and orange, mottled, very disturbed, gravelly, soft to slightly firm, calcareous zones and nodules, damp; at 11 ft. going into a gray colored silty clay.	Still fill material.
12			U/CLLR	Clay: As above; at 13.5 ft. hard limestone zone.	0.2 ft. Recovery.
14			U/CLLR	Clay: As above, still very disturbed.	
16			U/CLLR	Clay: As above, damp.	
18.1			U/SDSM	Sand: Light brown, very silty and clayey, saturated, minor small gravel, < 1% pebbles.	Very "muddy".
20			U/SDSM	Sand: As above.	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 25.2 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 11	
4. HOLE NO.: LF05-01		11. ELEVATION GROUND WATER: 603.82 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/22/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 619.30 ft MSL	
X: 2018791.38 Y: 399361.24		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 621.96 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
22			U/SDLR	Sand, Clay and Gravel: About equal % of each, saturated, shells, gravels to 20 mm, silty; 24.5 - 25 ft. mostly sand and gravel.	Still very "muddy".
25		50	U/MARL	Marl: Limestone, chalky, indurated, oxidation staining.	MOSS sampler refusal at 25 ft.; drive sample 50 blows = 2 in.; Fill probably ended about 18.1 ft. BLS; hole looked like fill all the way TD. T.D. = 25.2 ft.

DRILLING LOG | RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX | SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 27.2 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 13
4. HOLE NO.: LF05-02	11. ELEVATION GROUND WATER: 597.83 ft MSL (6/18/90)
5. NAME OF GEOLOGIST: S. E. Fain	12. DATE HOLE ESTABLISHED: 3/22/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 620.30 ft MSL
X: 2019492.00 Y: 399280.64	14. BACKGROUND:
	15. MEASURING POINT ELEVATION: 622.69 ft MSL

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Orange/brown, stiff, silty, abundant calcareous material, damp.	Full sampler unless noted.
2			U/CLLR	Clay: As above, 0.5 ft. caliche zone 3 - 3.5 ft.	1.2 ft. Recovery.
4			U/CLLR	Clay: Dark brown, stiff, carbonaceous staining, damp, silty.	No calcareous material.
6			U/CLLR	Clay: As above, minor gravel, silty.	
8			U/CLAY	Clay: Brown and tan mottled, distrurbed looking (not natural layering), damp; some greenish/gray clay also.	Looks like fill material.
10			U/CLAY	Clay: As above, soft calcareous zone at 11 ft.	1.0 ft. Recovery.
12			U/CLAY	Clay: Still heavily disturbed nature, 3 in. wet seam at 13 ft.	Still fill material.
14			U/CLLR	Clay: Becoming siltier, moist, some greenish/gray coloration.	
16			U/CLLR	Clay: Brown and green mottling, very disturbed nature, gravel (1 - 5%), shells; 0.4 ft. fine sand seam at 16.6 ft.; wet.	Still looks like fill.
18			U/CLLR	Clay: As above, silty, not disturbed; greenish/gray at 19 ft.	Greenish/gray material looks natural - in situ.
20			U/CLLR	Clay: Greenish/gray, silty, oxidation stained mottling, firm, damp, 1 - 3% assorted size sand and small gravel, gravelly sand at bottom.	W.L. measured at 21.05 ft. BLS after well completion.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 27.2 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 13	
4. HOLE NO.: LF05-02		11. ELEVATION GROUND WATER: 597.83 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/22/90	
6. COORDINATES OF HOLE: X: 2019492.00 Y: 399280.64		13. SURFACE ELEVATION: 620.30 ft MSL	
		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 622.69 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
24.9			U/SDGR	Sand and Gravel: Orange/brown, very clayey, saturated, numerous shell fragments, gravels to 40 mm, mainly limestone clasts.	
27		50	U/MARL	Marl: chalky, white/gray, shaley, indurated.	Sampler (MOSS) refusal at 27 ft.; drive 1 1/2 ft. SS 50 blows = 2 in.; T.D. = 27.2.

DRILLING LOG | RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX | SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 27.5 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 13
4. HOLE NO.: LF05-03	11. ELEVATION GROUND WATER:
5. NAME OF GEOLOGIST: S. B. Blount	12. DATE HOLE ESTABLISHED: 3/22/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 620.60 ft MSL
X: 2019488.64 Y: 399182.10	14. BACKGROUND:
	15. MEASURING POINT ELEVATION:

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Soft - firm, moist, clay fraction plastic - semi - brittle due to roots, calcareous pebbles, slightly silty with clayey silt 1.7 - 2 ft., yellow orange grading to brown.	Full recovery unless otherwise indicated. Extremely windy.
2			U/CLLR	Clay: As above, calcareous pebbles concentrated in intervals, less silty, minor carbonaceous streaking at base.	Gradational changes.
4			U/CLAY	Clay: As above, Brown, firm, fairly plastic, layers of concentrated calcareous debris.	
6			U/CLLR	Clay: As above, dark brown, grading darker, soft to firm, very few calcareous pebbles, abundant carbonaceous lamina, very few fine rootlets, moist, minor silt in lenses, plastic - appears organic rich.	
10			U/CLLR	Clay: As above, dark brown, soft, plastic, moist with silty/sandy lenses to 13.2 ft.; leached zones 13.2 - 13.5 ft., 14.3 - 14.4 ft., clay is white/buff, brittle, damp, with more frequent calcareous pebbles, intervening clay is as above; with silt/sand.	Musky odor. Caliche zones. 1.5 ft. recovery.
14.4			U/CLLR	Clay: As above soft/firm with abundant carbonaceous lamina, fine roots, dark brown, minor leached pebble zone 14.8 ft.	
15.2			U/SDSM	Sand: Buff. Moist to wet, very fine grained, silty, poor - moderate sorting.	Water in hole ~ 15 - 16 ft.. Sharp contact.
16			U/CLLR	Clay: As above, dark brown, carbonaceous stains, soft to firm, moist, calcareous pebbles, minor oxidation stains.	
16.5			U/SDLR	Sand: As above, silty, color lamina (oxidation layers), fine roots, gravel - 17.6 - 18 ft.; buff; sand is quartzose with > 95% quartz, minor cohesive clay lenses, otherwise loose, minor carbonaceous streaking; clay lenses and intermitent pebbles decrease to 20 ft.	Few pebbles.
20			U/SDGR	Sand: As above, buff yellow, and gravel to 22 ft., sand	Not likely fill

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 27.5 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 13	
4. HOLE NO.: LF05-03		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/22/90	
6. COORDINATES OF HOLE: X: 2019488.64 Y: 399182.10		13. SURFACE ELEVATION: 620.60 ft MSL	
		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
				is very poorly sorted; gravel approximately 20%, 2 - 15 mm, clayey with clay content increasing to bottom.	due to laminae above. Vague 'contacts'.
22			U/CLLR	Clay, silt and gravel: Light to medium grey to 22.3 ft., changing to buff/orange. Clay is stiff, wet and brittle. Gravel appears concentrated in horizontal planes. Abrupt color change to dark grey at 24 ft. Clay at 24 ft. is silty with minor calcareous pebbles, firm, semi-plastic	
26.5			U/GRVL	Gravel: Clayey, silty, sandy, loose, wet, medium grey, 80% of sample calcareous gravel 5 - 50 mm, average size 20 mm.	Auger refusal at 27.4 ft.; went in with SS. No Recovery.
27.4		50	U/MARL	Marl: See description from LF05-04 (no sample recovery).	T.D. at 27.5 ft.; WL approximately 24 ft.. (grouted before E - line).

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 28.3 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 14	
4. HOLE NO.: LF05-04		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/22/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 617.30 ft MSL	
X: 2019719.98 Y: 399313.92		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Sandy, brown with calcareous pebbles, damp, fine, semi - brittle, rootlets.	
1			U/SDLR	Sand: Brown/green, clayey, with gravel up to 15 mm, very poorly sorted, moist, quartzose with calcareous pebbles.	
1.5			U/CLLR	Clay: As above, calcareous pebbles increased to 25%, very brittle with oxidation blebs and black carbonaceous staining within lenses, less sandy.	Probably fill. 3.5 ft. Recovery.
5			U/SDLR	Sand: Brown, loose, dry to damp, very fine grained, slightly clayey, poor - moderately sorted, quartzose with calcareous pebbles, oxidation lenses and asphaltic pebbles.	Probably fill. 3.5 ft. Recovery.
7			U/CLLR	Clay: Light brown orange, firm, semi-plastic with calcareous pebbles to 8 ft.	
8			U/SDLR	Sand: As above.	
9.5			U/CLLR	Clay: As above.	
10			U/SDLR	Sand: Orange brown, clayey, silty, very fine grained, poorly sorted, oxidation stained, quartzose with > 95% quartz, subrounded, with 5% carbonaceous flecks and several large (40 mm) gravel chunks, moist to 12 ft., wet at 13 ft., minor carbonaceous streaking.	Fill, Concrete block in sample ~ 2 in. across. Sarp contract. 3 ft. Recovery.
13			U/CLLR	Clay: Buff yellow, wet, silty, oxidized, soft to firm, plastic, caliche at top, minor pebbles (calcareous) to 14 ft.	Bottom of fill - sharp. Water in hole.
14			U/CLLR	Clay: Very stiff, green/grey, abundant calcareous debris, semi-brittle, wet carbonaceous stained.	
14.8			U/CLLR	Clay: Dark brown/black, very brittle, organic rich, moist, fine rootlets, gradual color change to green/grey with an increase in carbonaceous debris and plasticity; very stiff; similar to clay at 14 ft.	Sharp contract. Musky odor.
18			U/CLLR	Clay: As above with an increase in gravel and sand to 20 ft. (clay and gravel). Green/grey, stiff, brittle, calcareous pebbles concentrated in 0.5 ft. intervals to 23 ft.; sandy in these intervals (CaCO3 sand?).	Calcareous zones 'calichified'.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 28.3 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 14	
4. HOLE NO.: LF05-04		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/22/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 617.30 ft MSL	
X: 2019719.98 Y: 399313.92		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
23			U/SDGR	Sand and Gravel: Sand is very fine to coarse grained, saturated, very poorly sorted, buff/tan, sub-rounded, quartz and CaCO3, (60% quartz) and < 5% heavy minerals, minor oxidation staining, 'gravel' average size 5 mm, but up to 35 mm, quartz and CaCO3, approximately 40% of sample	Very sharp contract.
28		50	U/MARL	Marl: Fissile, calcareous, hard, wet, chalky, w/ shell fragments; (description from bit sample and portion of SS recovery).	1 ft. Recovery last ST; drive SS. SS refusal. Went in with auger to check, auger refusal. T.D. = 28.3 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 26.2 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 14	
4. HOLE NO.: LF05-05		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/22/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 616.10 ft MSL	
X: 2019785.85 Y: 399388.49		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/SDCL	Sand and Clay: Orange/red, very fine grained, damp, with asphalt, gravel, roots, calcareous fragments, very poorly sorted sand, cohesive (clay).	Full sample unless otherwise indicated. 1 ft. Recovery. Fill sand top 2 ft.
2			U/CLLR	Clay: Brown, with minor orange mottling, firm, semi - plastic with abundant calcareous pebbles (up to 20 mm), damp to moist, minor black (carbonaceous?) streaking.	Fill clay.
4			U/CLLR	Clay: As above - light brown, mottling increased. Asphalt? mixed with sample.	Fill clay?
6			U/CLLR	Clay: As above.	
8			U/CLLR	Clay: As above, few large (50 mm) gravel chunks.	
9.9			U/ASPH	Asphalt: Solid "asphalt" - tar and pea gravel with some brown clay.	Fill. Could not push at 10 ft.; material very hard.
12		11,13,17	U/CLLR	Clay: Dark grey/very dark grey mottled, firm, semi-plastic with abundant calcareous pebbles (1 to 15 mm) and fragments, damp to moist with indurated sandy caliche layer - light orange/buff at base.	Limestone lithoclast?
14			U/CLLR	Clay: As at 12 ft. Few very large cobbles (80 mm); silty 14.4 - 14.8 ft.; color lightening.	
16			U/CLLR	Clay: As above, color change at 16.4 ft. to buff/tan/yellow; continued large cobbles to 18.5 ft., calcareous debris abundant at 17.2 - 17.6 ft. then ends abruptly.	
18			U/CLLR	Clay: Soft to slightly firm, buff/yellow, 20% small calcareous fragments and sand and silt, moist to wet, semi-plastic, few 15 mm pebbles.	
20			U/SDLR	Sand, Gravel and Clay: As above, sand or gravel up to 50%; soft, wet at top. Firm, plastic at base; semi-brittle due to inclusions; calcareous fragments increase to base, clayey sandy gravel to base (clayey	Samples preferentially wet (soggy) on top; probably a function

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 2 SHEETS

1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 26.2 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 14
4. HOLE NO.: LF05-05	11. ELEVATION GROUND WATER:
5. NAME OF GEOLOGIST: S. B. Blount	12. DATE HOLE ESTABLISHED: 3/22/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 616.10 ft MSL
X: 2019785.85 Y: 399388.49	14. BACKGROUND:
	15. MEASURING POINT ELEVATION:

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
				gravely sand).	of the sampler. Clay, sand, and gravel equal proportions.
24.9			U/GRCL	Gravel: Clayey gravel.	
25.3			U/SDSM	Sand: Clay bound gravelly sand; sand composed of shell (calcareous) fragments, coarse grained, wet, poorly sorted.	
26		50	U/MARL	Marl: Buff/yellow, fissile, shells, clayey shale appearance, semi-indurated, chalky.	Refusal at 26 ft., Drive SS. T.D. at 26.2 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 1 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 7.7 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 5	
4. HOLE NO.: LF05-06		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/22/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 598.30 ft MSL	
X: 2020129.68 Y: 399156.86		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/SDGR	Sand, Gravel, and Clay: Buff/yellow, very poorly sorted; sand is very fine to very coarse grained, quartzose with calcareous pebbles/fragments, moist to 3 ft., wet below; clay content increases below 3 ft.. Gravel (20%) up to 20 mm, size increases at base. Unit is brittle.	Full recovery unless otherwise noted.
4			U/SDGR		1.5 ft. Recovery, ST refusal at 5.5 ft., go in with auger to 5 ft. samples.
5.8			U/GRSM	Gravel: Average 70 mm, minor fine sand and clay, moderately well sorted, subrounded, composed of limestone lithoclasts.	
6.5			U/CLAY	Clay: Stiff to very stiff, buff/yellow, with grey mottling, brittle, moist; oxidation staining throughout, fissile in zones.	
7		50	U/MARL	Marl: Dark grey, semi-indurated, very fissile, highly calcareous, leached 'caliche' type zone at base (0.1 ft.).	Refusal at 7.5 ft. (limestone), drove SS at 7.5 ft.. Less than 3 in. with 50 blows. T.D. at 7.7 ft.. WL = 3.38 ft. BGL.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 1 SHEETS

1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 7.2 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 6
4. HOLE NO.: LF05-07	11. ELEVATION GROUND WATER:
5. NAME OF GEOLOGIST: S. B. Blount	12. DATE HOLE ESTABLISHED: 3/22/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 598.00 ft MSL
X: 2020230.22 Y: 399192.73	14. BACKGROUND:
	15. MEASURING POINT ELEVATION:

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Brown/grey, moist, soft, plastic, roots, sandy, with increased sand to 0.8 ft. becoming clayey sand.	
1			U/GRSM	Gravel: Clayey, light brown/grey, calcareous gravel up to 25 mm (mostly 2 - 3 mm), moist, very poorly sorted.	Sharp contact. 2 ft. Recovery.
1.4			U/SDGR	Sand and Gravel: Very fine grained, poorly sorted, clayey, orange, dry to damp, with moisture increasing to base. Clay content variable, clayey and cohesive in lenses; gravel ~ 20%, 3 - 25 mm, very poorly sorted.	Sharp contact. Assume some gravel lost in first sample.
3.8			U/GRSM	Gravel: Quartz and calcareous pebbles with minor sand, wet, very poorly sorted; 98% gravel, average 10 mm up to 20 mm.	Sharp contacts.
5			U/CLAY	Clay: Stiff to very stiff, buff/yellow with gray mottling, oxidation seams, semi-fissile, brittle, moist.	3 ft. Recovery. Refusal at 5.8 ft..
5.8		50	U/MARL	Marl: Dark gray, semi-indurated, very fissile, highly calcareous, alternating with stiff 'clay', minor oxidation mottling.	Drilled into marl 1.4 ft. to good auger refusal. T.D. = 7.2 ft.. No WL hole caved to 3.5 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 1 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 18.3 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 9	
4. HOLE NO.: LF05-08		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/22/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 606.80 ft MSL	
X: 2020350.89 Y: 399030.31		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLAY	Clay: Brown, soft, damp, brittle, root bound with fine rootlets, minor other plant debris.	
2			U/CLAY	Clay: Medium brown, firm, plastic, moist, minor rootlets, few calcareous flecks at base.	
4			U/CLAY	Clay: Grey/grey, mottled, very stiff, dry to damp, very minor fine rootlets, abundant calcareous debris.	Could not cut w/ carpet knife.
8			U/CLLR	Clay: As above, calcareous pebbles up to 15 mm; stiff. Predominately debris 1 - 2 mm.	Pebbles effervesce in HCl solution.
10			U/CLLR	Clay: As above, firm, plastic.	
11			U/CLLR	Clay, Sand, and Gravel: Very poorly sorted, rounded gravel, moist. Clay dominates to 12 ft. with small soil developed on top, buff/yellow. Sand content increases to base.	Musky odor. Terrace dep.? (Soil).
12			U/SAND	Sand: Buff/yellow, very fine to fine grained, slightly clayey/cohesive at top, loose below 12.3 ft., moderate rounding, well sorted, > 95% quartz.	Water in hole at 12 ft.; go to 5 ft. samplers.
14.5			U/LMSN	Limestone: Grey to light grey, marly, fissile, weathered. 10 mm indurated layers with thin marls between, no shells, micritic appearance.	Drilled slowly into limestone. Refusal at 14.5 ft. 0.5 ft. Recovery. Driller says layered marl, drive SS; 1 ft. Recovery.
17.5		50	U/LMSN	Limestone: Well indurated, calcareous shale - fissile, medium grey, slightly 'carbonaceous'; contiguous 'bed' from 17.5 - 18.3 ft.	T.D. at 18.3 ft.. Water level = 12.67 ft. (BGL).

73 275

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 1 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 14.5 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 6	
4. HOLE NO.: LF05-09		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/22/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 604.90 ft MSL	
X: 2020361.60 Y: 398918.32		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Orange/brown mottled, very sandy, silty with some gravel, brittle, dry to damp, fine rootlets to 3.5 ft., few calcareous flecks, alternating zones: brown then orange approximately 0.5 ft. thick.	Full recovery unless otherwise indicated.
3.5			U/SDSM	Sand: Buff/yellow with orange color laminations, slightly clayey at top, loose below, rounded quartzose grains; clay lenses 5 - 5.3 ft., 5.7 -5.9 ft.; damp to moist, > 95% quartz, well sorted, cohesive in clayey intervals, loosely consolidated otherwise.	Sharp contact.
8			U/SDSM	Sand: As above, thinly laminated orange color laminae are contorted, slightly clayey at base.	
10			U/SDSM	Sand: As above, moist to wet, clayey at top. Shell fragment layer 10.6 - 11.4 ft.. Clayey and silty below.	Water in hole ~ 11 ft.
12			U/SDLR	Sand: Orange, very minor gravel, wet loose, few carbonaceous streaks.	3 - 6 pieces of 10 - 20 mm gravel.
14		50	U/MARL	Marl: Indurated, dark grey/green shale, very calcareous, some orange oxidation, fissile, few shell fragments, minor carbonaceous debris, dry to damp.	Refusal at 14 ft.; drove SS, bottomed less than 0.5 ft.. T.D. at 14.5 ft.

72-276

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 36.2 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 13	
4. HOLE NO.: LF05-10		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/22/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 623.90 ft MSL	
X: 2019456.19 Y: 398656.87		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Medium dark brown with minor carbonaceous streaking, firm, plastic, moist. Calcareous pebbles abundant to 0.4 ft., minor roots, few pebbles to 3 ft.	Full recovery unless otherwise noted.
3.2			U/CLLR	Clay: Very stiff, dark brown with obvious carbonaceous streaking, minor sandy lenses, damp to moist, brittle, hard, sand lamination at upper contact is parting; fine rootlets and intervals with coarse sand/pebbles to 6 ft.	Can not cut - seems too dense to be fill. 1 ft. Recovery in ST. Crushed heavy guage sampler.
6			U/CLLR	Clay: Calichified (leached) white to buff, brittle, firm, shell fragments, damp, abundant calcareous debris, abundant orange oxidation seams, visible authigenic mineralization, silty appearance.	Full 2 ft. push with no recovery. SS pushed 6 - 8 and got 0.9 ft. recovery.
7.5			U/CLLR	Clay: Stiff, as above, interlayered with calichified zones to 13.2 ft.; stiff clay has intervals of abundant calcareous debris and grades into caliche then abruptly goes back to clay as 6 - 7 ft.	Pushed SS - 0.8 ft. Recovery; used 5 ft. sampler from 12 - 14.5 ft.; 0.3 ft. recovery.
13.2			U/CLLR	Clay: Medium brown/yellow, moist to wet, brittle, silty, abundant calcareous debris.	
14.5			U/MARL	Marl: Weathered limestone marl at 14.5 ft.; clay rich, soft, oxidized in seams, abundant broken micritic limestone fragments, wet (saturated - soggy), semi-plastic, buff/yellow.	Water in hole 14.5 - 19.5 ft.. 3.5 ft. recovery.
16			U/CLLR	Clay and Gravel: Gravel < 20%, clay is buff, firm to stiff, moist, oxidation seams, chalky, $CaCO_3$, rich, with coarse fragments, silty, semi-fissile.	
18			U/MARL	Marl: Dark grey, semi-indurated, highly calcareous, shaley, fissile, dense, dry to damp.	
19.5			U/GRSM	Gravel, Sand, and Clay: Gravel up to 80%, orange/yellow, brittle/friable, soft, wet to moist. Sand very poorly sorted, very fine to coarse grained, subangular, wet, gravel up to 40 mm, quartz and $CaCO_3$ and minor shell fragments, slightly cohesive.	4.2 ft. Recovery.

DRILLING LOG | RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX | SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 36.2 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 13
4. HOLE NO.: LF05-10	11. ELEVATION GROUND WATER:
5. NAME OF GEOLOGIST: S. B. Blount	12. DATE HOLE ESTABLISHED: 3/22/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 623.90 ft MSL
X: 2019456.19 Y: 398656.87	14. BACKGROUND:
	15. MEASURING POINT ELEVATION:

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
23.9			U/SLCL	Silt: Orange, clayey (slightly), wet, soft, minor oxidation staining in laminae, very uniform lithology throughout interval, saturated.	Very sharp contact.
28.5			U/SDLR	Sand: Orange/yellow, very fine grained, loose, saturated, > 95% quartz, moderately well sorted, subrounded grains, no sedimentary structures, minor oxidation pods, very minor carbonaceous flecks; with few large (50 - 100 mm gravel fragments)	Very sharp contact.
33.2			U/GRSM	Gravel: Quartz and calcareous fragments, poorly sorted, wet, slightly sandy, slightly silty, loose, average 2 - 6 mm of subangular fragments up to 75 mm; buff/orange.	Sharp contact. 34.5 - 36 ft. = NR.. Auger refusal at 36 ft.; drive SS. Grout SS refusal.
36		50	U/MARL	Marl: Limestone fragment - well indurated, micrite. Buff, few recrystallized fossils, chaulky exterior.	T.D. at 36.2 ft.. Poor recovery SS, description from one fragment. WL = 26.2 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 1 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 10.1 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 6	
4. HOLE NO.: LF05-11		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 597.60 ft MSL	
X: 2020446.51 Y: 398619.94		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLAY	Clay: Dark brown, damp, calcareous nodules, roots.	Full recovery unless otherwise noted.
2			U/CLLR	Clay: As above, slightly silty and sandy.	
4			U/CLLR	Clay: Dark brown, hit root at 5.5 ft., wet.	1.2 ft. Recovery.
6			U/CLLR	Clay: Green/orange, very fine grained sand.	W.L. measured at 3.05 ft. BLS.
7			U/SDLR	Sand: Orange/tan, fine to medium grained, wet, quartzose; at 8 ft., brown, musky odor. 8.5 - 10 ft. increasing gravel to 20% at bottom of sampler. Saturated, shells.	
10			U/MARL	Marl: Green/gray, indurated, fissile, exogyra fossils.	Auger refusal at 10 ft. Drove S.S. (1 1/2 ft.); 50 blows = 0.1 ft.; T.D. = 10.1 ft.

72 279

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 1 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 9.2 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 6	
4. HOLE NO.: LF05-12		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 594.40 ft MSL	
X: 2020606.71 Y: 398699.09		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay, Sand, Gravel: Clay is light brown/orange, moist, semi-plastic, soft with abundant oxidation. Gravel is 10 - 20 mm calcareous pebbles.	Full sample unless otherwise indicated.
1.5			U/SDSM	Sand: Orange, moist, clayey 2 - 2.5 ft., silty, very fine grained, poorly sorted.	Gradational contact.
2.5			U/CLLR	Sandy Clay: Clay as above, without gravel (calcareous debris minor), sandy and silty to 4 ft.; silty to 6.8 ft.; clay is grey/brown, moist, soft; very soft and wet at 5 ft., minor oxidized sand seams, few very fine rootlets, semi-plastic.	Water in hole at 5 ft.
6.8			U/CLAY	Clay: Dark grey/black, soft, plastic, wet, highly organic, few fine rootlets, silty (minor).	Sharp contact. Musky odor. 1 ft. Recover ST. Marl at sample bottom.
8.8			U/SDVF	Sand: Very fine grained, moderately sorted, dark grey, carbonaceous streaking, wet, quartzose.	
9		50	U/MARL	Marl: Medium grey, fissile, well indurated, micritic, brittle in chaulky zones.	T.D. at 9.2 ft.; WL = 2.73 ft.

73 280

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 1 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 17.1 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 9	
4. HOLE NO.: LF05-13		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 605.00 ft MSL	
X: 2020738.54 Y: 398406.77		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLAY	Clay: Dark brown, damp, roots, plastic; calcareous zone starts at 1.8 ft.	Full recoveries unless noted.
2			U/CLLR	Clay: Orange/brown, very silty, abundant calcareous material (caliche), dry, slightly cohesive.	1.6 ft. Recovery.
4			U/CLLR	Clay: As above, 20 - 30% calcareous material.	
6			U/CLLR	Clay: As above, moist; increased calcareous material, 8.7 - 9.3 ft. Aalmost completely calcareous material.	1.4 ft. Recovery.
9.3			U/SAND	Sand: Orange/tan, fine to medium grained, loose, damp, subround, quartzose, minor oxidation staining.	Pushed S.S. sampler (1.5 ft.).
12			U/SDLR	Sand: As above, calcareous zones (~ 0.5 ft.) at 13 ft. and 14 ft.; also gravelly in these zones. Material saturated at ~ 13.5 ft.	Could not get W.L. down hole after augers pulled; 4.5 ft. Recovery.
15			U/SDLR	Sand: As above.	
16			U/SDGR	Sand and Gravel: 50/50, very fine sand to pebble size gravel, saturated, numerous shells.	Sampler refusal at 17 ft.
17		50	U/MARL	Marl: Gray/green, fissile, indurated, iron stained in fractures, calcareous.	Driving 1 1/2 ft. S.S. 1 1/4 in. for 50 blows; T.D. = 17.1 ft.

73 281

DRILLING LOG — RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX — SHEET 1 OF 1 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 13.3 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 8
4. HOLE NO.: LF05-14	11. ELEVATION GROUND WATER: 594.14 ft MSL (6/18/90)
5. NAME OF GEOLOGIST: S. B. Blount	12. DATE HOLE ESTABLISHED: 3/19/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 603.20 ft MSL
X: 2020910.08 Y: 398467.53	14. BACKGROUND:
	15. MEASURING POINT ELEVATION: 602.98 ft MSL

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Very dark brown, soft, dry to damp, brittle/crumbly, fine rootlets and calcareous pebbles, abundant calcareous debris 1.5 - 2 ft.; silty, sandy.	Full recovery unless noted otherwise. 3 ft. Recovery.
2			U/CLAY	Clay: Brown/tan, firm, dry to damp, abundant calcareous debris, 'crumbly' carbonaceous particles, stiffens to base.	
3.5			U/CLLR	Clay: As above, calichified to 4 ft., very stiff, dry, silty, sandy to 4.7 ft., clay below is orange brown, very stiff, damp with abundant calcareous debris and carbonaceous streaks/particles, brittle, sandy.	3.5 ft. Very hard to cut.
7.2			U/MARL	Marl: Light grey, very stiff, silty clay with abundant large CaCO3 fragments, oxidized in seams, brittle, moist, 'slickensided'.	
8.5			U/SDFN	Sand: Fine grained, orange tan, oxidized, moderately sorted, subrounded, wet, loose, quartzose with > 95% quartz and < 5% heavy minerals.	2.5 ft. Recovery.
8.7			U/SDGR	Sand and Gravel: Sand as above with gravel at 8.7 ft., gravel is predominately CaCO3 fragments, poorly sorted (some quartz) average 3 mm, up to 30 mm. Approximately 40% of sample; subrounded.	Water in hole at 9 ft.
10.5			U/GRSM	Gravel and Sand: As above, only gravel 60 -70% of sample, few large > 70 mm fragments.	Driller says limestone at 13 ft.
13		50	U/MARL	Marl: Very hard - no recovery.	Drove SS; 50 blows went 1 in.; no recovery; T.D. at 13.3 ft.; WL - 9.43 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 3 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 40.6 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 26	
4. HOLE NO.: LF05-15		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 626.50 ft MSL	
X: 2019457.49 Y: 398082.81		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Dark brown, firm, moist, semi-plastic to 1.8 ft.; calcareous pebbles aligned horizontal in "beds" to 1 ft.; rootlets, organic, slightly silty 1 - 2 ft.	Full recovery unless otherwise indicated.
2			U/CLLR	Clay: As above, leached to buff color with oxidation staining, abundant calcareous pebbles 1.8 - 2.1 ft.	
2.1			U/CLLR	Clay: As first clay with pebbles and semi-leached zone, pebbles and clay 3 - 3.2 ft., interval from 2.1 - 4.4 ft. orange/brown. Alternating zones of dark brown firm clay with abundant calcareous debris and orange/brown, softer with pebbbles; thin sand 3.6 - 3.8 ft., very fine gra	Alternating zones 3 - 6 ft. each approximately 0.3 ft. thick.
6			U/CLLR	Clay: Slightly sandy, silty, minor calcareous debris, very soft, saturated (soggy), oxidation stained throughout, minor carbonaceous streaking, few very fine rootlets, orange/brown.	Water in hole at 7 ft. Perched?
8			U/CLLR	Clay: As above, firm, dark brown clay with few pebbles from 9.8 - 10 ft.; no silt, very sandy at top.	
10			U/CLLR	Clay: As above, very sandy at top with dark brown, firm to stiff clay at 11 - 12.1 ft., oxidation streaked.	Clayey sand?
12.1			U/CLLR	Clay: As above, no roots, minor calcareous debris.	Sandy/soggy top very regular - function of sampler?
14.1			U/SDCL	Clayey Sand: Orange - very fine grained, saturated, cohesive, very poorly sorted, quartzose, minor carbonaceous stain, 14.1 - 14.8 ft.	
15			U/CLLR	Clay: Dark brown-black, firm to stiff.	
15.9			U/CLLR	Clayey Sand: As above, 15.9 - 16.3 ft.	
17			U/SDCL	Sand: As above.	
17.5			U/CLLR	Clay: As above, dark brown to black, minor calcareous pebbles, firm to stiff, moist to wet, abundant carbonaceous stains, minor oxidation.	
18			U/SDSM	Sand: Silty, clayey, saturated, as above 18 - 18.6 ft.	Very regular - fill?
19			U/CLLR	Clay: As above.	
19.9			U/CLLR	Clay: Caliche layer between 19.9 - 20 ft. and between 21.8 - 22 ft. with intervening clay, as above.	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 3 SHEETS

1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 40.6 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 26
4. HOLE NO.: LF05-15	11. ELEVATION GROUND WATER:
5. NAME OF GEOLOGIST: S. B. Blount	12. DATE HOLE ESTABLISHED: 3/19/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 626.50 ft MSL
X: 2019457.49 Y: 398082.81	14. BACKGROUND:
	15. MEASURING POINT ELEVATION:

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
22			U/CLLR	Clay: As above, with abundant calcareous debris.	
23.4			U/SLCL	Silt: Tan/orange, slightly clayey, wet, slightly sandy, no sedimentary structures, cohesive.	First push on ST had no recovery; pushed SS - full recovery.
25.4			U/SDSM	Sand: Tan/orange, very fine grained, moderately well sorted, quartzose with > 95% quartz, minor carbonaceous lamina, subrounded, wet/saturated, loose, grading to silt.	Sharp contact. Driller says hard and soft layers when augering between 15 and 25 ft.
26			U/SILT	Silt: As above, no clay, grading to silty sand (sand as above); silty to 29.3 ft.	
29.3			U/SDSM	Sand: As above, no silt, no sediment structures, except minor dark carbonaceous laminae.	
32.2			U/GRSM	Gravel: Orange, very poorly sorted, $CaCO_3$ and quartz; $CaCO_3$ fragments all > 15 mm; quartz fragments most of smaller; subrounded, slightly sandy, wet, loose, average fragment equals 5 - 10 mm up to 75 mm, slight clay/chalkiness.	Sharp Contact.
36			U/GRVL	Gravel: Very 'clean', better sorting, predominately quartz, no sand/clay, minor shell fragments.	Sharp Contact.
37.1			U/GRVL	Gravel: Clean as above.	
39.5			U/GRVL	Gravel: Darker in color, black staining throughout.	TCE? No reading HNU/Drager.
40			U/SDGR	Sand and Gravel: Fine grained gravel and sand, poorly sorted, very loose, with broken shell fragments.	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 3 OF 3 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 40.6 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 26	
4. HOLE NO.: LF05-15		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE: X: 2019457.49 Y: 398082.81		13. SURFACE ELEVATION: 626.50 ft MSL	
		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
40.4		50	U/MARL	Marl: Buff, clayey/chaulky, predominantly welded crystallized shell fragments, fissile to brittle, semi-indurated, wet.	39.5 - 44.5 ft. recovered 2.5 ft., but 1.5 ft. was sluff. Auger refusal at 40.5 ft., went in with SS; 50 blows and 1.5 in. recovery; T.D. at 40.6 ft.

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DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 23.1 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 12	
4. HOLE NO.: LF05-16		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 612.30 ft MSL	
X: 2021041.70 Y: 398229.39		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLAY	Clay: Brown with orange cast, soft to firm, soil top, rootlets to bottom, dry to damp, semi-plastic.	Full sample recovery unless otherwise noted.
2			U/CLLR	Clay: Brown, very stiff, brittle, abundant calcareous fragments/shells, very minor rootlets, minor carbonaceous flecks, dry to damp.	Can not cut with knife.
4			U/CLLR	Clay: 'Caliche' - dessication cracked, white/brown/buff mottled, calcareous debris up to 10 mm, dry, 'hard' - stiff/brittle.	0.2 ft. Sample recovery.
6			U/CLLR	Clay: 'Caliche' as above, well indurated intervals, brittle, dry; limestone inclusions up to 20 mm.	1 ft. Recovery to refusal at 7 ft.
7			U/CLLR	Clay: Caliche as above, thin indurated zones; mostly dry, very stiff, highly calcareous buff/orange clay with inclusions as above, minor carbonaceous flecks; sandy from 8 - 8.5 ft.	Driller says limestone; will drive 7 - 8.5 ft.; full recovery SS.
9			U/SDSM	Sand: Abundant calcareous debris to 9.6 ft. - red, fine grained with silt, quartzose, dry and angular to 9.6 ft.; sand below 9.6 ft. is orange/yellow, very fine grained, loose, subangular, > 95% quartz, dry.	ST from 9 - 10 ft. Full recovery.
10			U/SDLR	Sand: As above, thin gravel horizions developed 10.5 - 10.8 ft., 12 - 12.6 ft.; color laminae ~ 3 mm - orange/yellow. Gravel up to 30 mm; minor gravel in sand very fine grained - fine grained, orange to 15 ft.	
14			U/SDLR	Sand: As above.	
16			U/SDLR	Sand: As above, few gravel/calcareous concretions throughout, moist at 16.5 ft, wet at 18.5 ft., gravel up to 50 mm, minor color laminae.	Not sufficient gravel to be classified as sand and gravel (10%); water at ~ 19 ft.
19			U/SDLR	Sand: As above, minor very coarse sand/fine gravel, sand is tan/orange, very fine grained, saturated, quartzose, subangular, > 95% quartz with moderate sorting.	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 1 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 16.6 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 9	
4. HOLE NO.: LF05-17		11. ELEVATION GROUND WATER:	
5. NAME OF GEOLOGIST: S. B. Blount		12. DATE HOLE ESTABLISHED: 3/19/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 606.50 ft MSL	
X: 2021241.43 Y: 398317.23		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION:	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Brown, soft - firm, silty with minor very fine grained sand, roots, moist, minor calcareous pebbles and carbonaceous staining, semi-plastic.	Full recovery unless otherwise noted.
3			U/CLLR	Clay: As above at 3 ft., with abundant calcareous pebbles.	
3.2			U/GRCL	Gravel, Clay, and Sand: Gravel is calcareous, dry to damp, calichified, < 15 mm, buff, wetness increases with depth, very poorly sorted with clay lenses. Clay is as above.	Gravel Contacts.
4.5			U/SAND	Sand: Sand is very fine grained - fine grained, orange oxidized at top grading to buff/yellow at 5 ft., subrounded, moderately well sorted, moist, quartzose with > 95% quartz, small shell fragments abundant to 10 ft. Grain size up to sand/gravel at 6.8 ft., then very fine grained	Sharp Contact.
9.4			U/CLLR	Clay: Minor shell fragments.	
10			U/SDVF	Sand: As above, very fine grained, well sorted, subangular to subround, moist to wet, color laminated, > 95% quartz.	2.5 ft. Recovery.
14			U/SDVF	Sand: As above.	No visible contamination, but high Drager readings 1 ft. Recovery.
16			U/SDVF	Sand: As above.	No odor.
16.5		50	U/MARL	Marl/Limestone: Micritic, light grey, dense, many small fossils (recrystallized), well indurated, chaulky surface.	Sample description from small fragments, apparently very hard. T.D. at 16.6 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 24.0 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 10	
4. HOLE NO.: LF05-18		11. ELEVATION GROUND WATER: 594.11 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/21/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 612.10 ft MSL	
X: 2021280.30 Y: 398169.30		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 611.84 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
					completion. No gravels.
23.2			U/MARL	Marl: White/gray, indurated, oxidation staining in fractures.	Drove 1 1/2 ft. S.S., 50 blows. 2 in. recovery. T.D. = 23.95 ft.

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 20.8 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 9	
4. HOLE NO.: LF05-19		11. ELEVATION GROUND WATER: 593.54 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/21/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 606.30 ft MSL	
X: 2021663.85 Y: 397850.57		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 606.08 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLAY	Clay: Dark brown first 1 ft., then orange/brown with abundant calcareous material, damp, cohesive.	0.3 ft. Recovery. Stuck in shelby tube.
2			U/SDMD	Sand: Orange, cemented 3 - 4 ft., medium grained, dry.	
4			U/SAND	Sand: Orange, fine to medium grained, quartzose, damp, loose.	1 ft. Recovery.
6			U/LMSN	Limestone: 1 in. limestone bed underlain by 2 in. cemented sand at 6.0 ft.	
6.3			U/SDGR	Sand and Gravel: Orange, poorly sorted, very fine grained sand to pebble size gravel, damp. Gravel is subround.	1 ft. Recovery.
10			U/SDGR	Sand and Gravel: Orange, 60% sand, 40% gravel, damp, oxidation staining 11 - 13 ft; occasional limestone cobbles and thin beds, saturated at ~ 13.5 ft.	4.2 ft. Recovery.
13.7			U/GRSM	Gravel and Sand: As above but > 80% gravels (mainly 2 - 10 mm), saturated, assorted sand sizes, gravels mainly subround chert and angular limestone clasts.	W.L. measured at 13.6 ft. 3.6 ft. Recovery.
19			U/GRSM	Gravel and Sand: 80% gravels 2 to 25 mm, 20% assorted sand sizes, saturated, numerous shells (gryphea?); 19 - 19.3 ft. medium sand bed.	

DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2		7. TOTAL DEPTH OF HOLE: 20.8 ft BGL	
		8. DATUM FOR ELEVATION SHOWN: sea level	
2. LOCATION: Flightline Area		9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61	
3. DRILLING AGENCY: Environmental Drillers, Inc.		10. NO. OF SAMPLES TAKEN: 9	
4. HOLE NO.: LF05-19		11. ELEVATION GROUND WATER: 593.54 ft MSL (6/18/90)	
5. NAME OF GEOLOGIST: S. E. Fain		12. DATE HOLE ESTABLISHED: 3/21/90	
6. COORDINATES OF HOLE:		13. SURFACE ELEVATION: 606.30 ft MSL	
X: 2021663.85 Y: 397850.57		14. BACKGROUND:	
		15. MEASURING POINT ELEVATION: 606.08 ft MSL	

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
20.5		50	U/MARL	Marl: Limestone, weathered, tan/white, indurated but heavily fractured, oxidation staining on fracture faces.	Sampling hard at 20 - 20.5 ft.; Drove 1 1/2 ft. S.S., 50 blows = 2.5 in. T.D. = 20.75 ft.

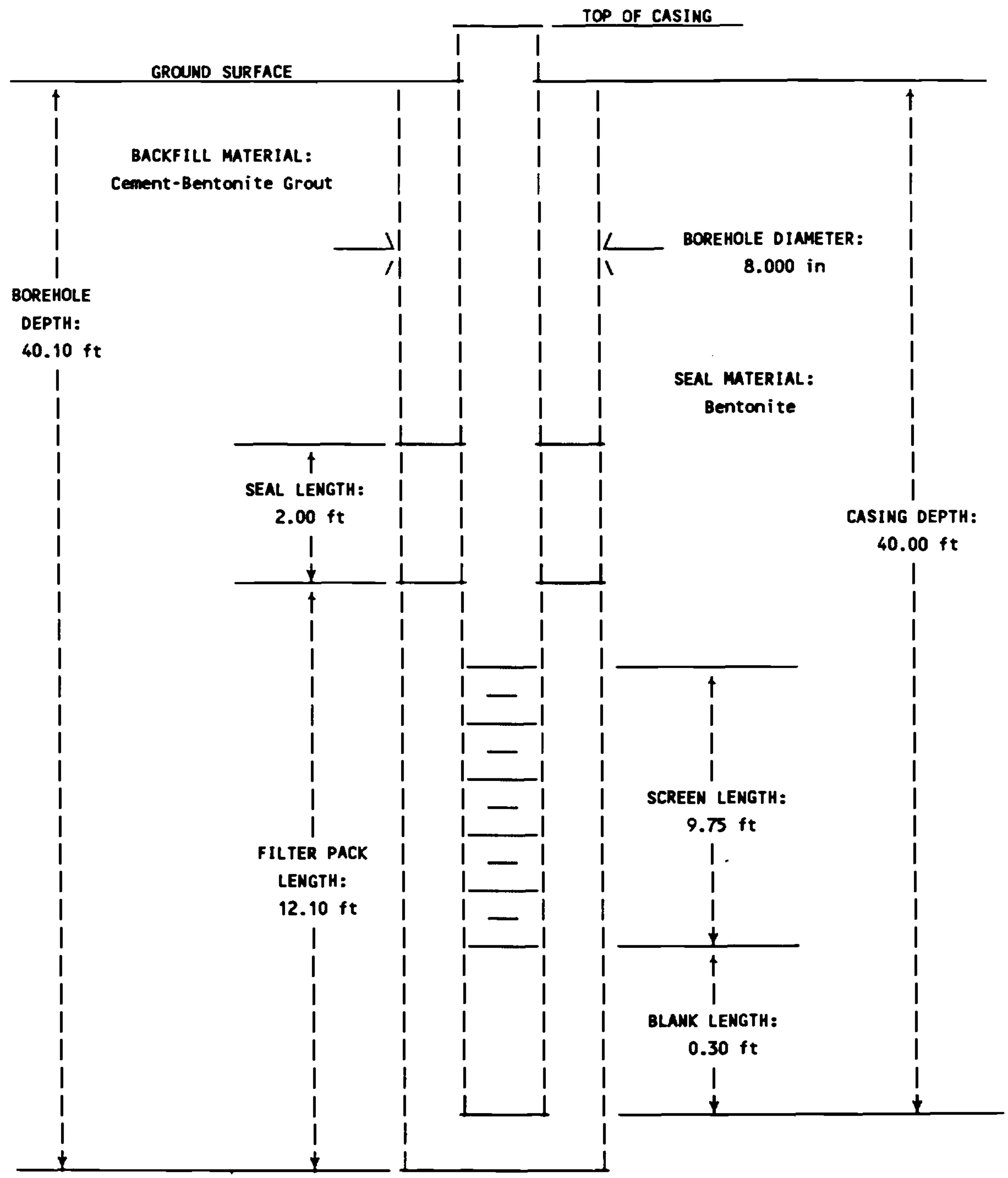
APPENDIX B

Well Completion Summaries

(Previous Well Completion Summaries may be found in CH2M Hill (1984), Radian (1986), and Radian (1989))

WELL COMPLETION LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB		9. INSTALLATION DATE: 3/23/90
		10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF04		11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation		12. SEAL END DEPTH: 28.00 ft
4. WELL NO.: LF04-01		13. MEAS. POINT ELEV.: 629.24 ft MSL
5. WELL OWNER: U.S. AIR FORCE		14. CASING DIAMETER: 2.00 in
6. WELL TYPE CLASS: MONITORING WELL		15. CASING MATERIAL: Schedule 40 PVC
7. FORMATION OF COMPLETION:		16. SCREEN BEGIN. DEPTH: 29.95 ft
8. LOCATION TYPE: WL		17. SCREEN SLOT SIZE: 0.02 in

18. REMARKS: 1-10'x2"x0.02" Screen,3-10'x2" Risers, Bottom Plug 1-Locking Cap,1-5'x2" Riser



FILTER PACK MATERIAL: 8-20 Silica Sand

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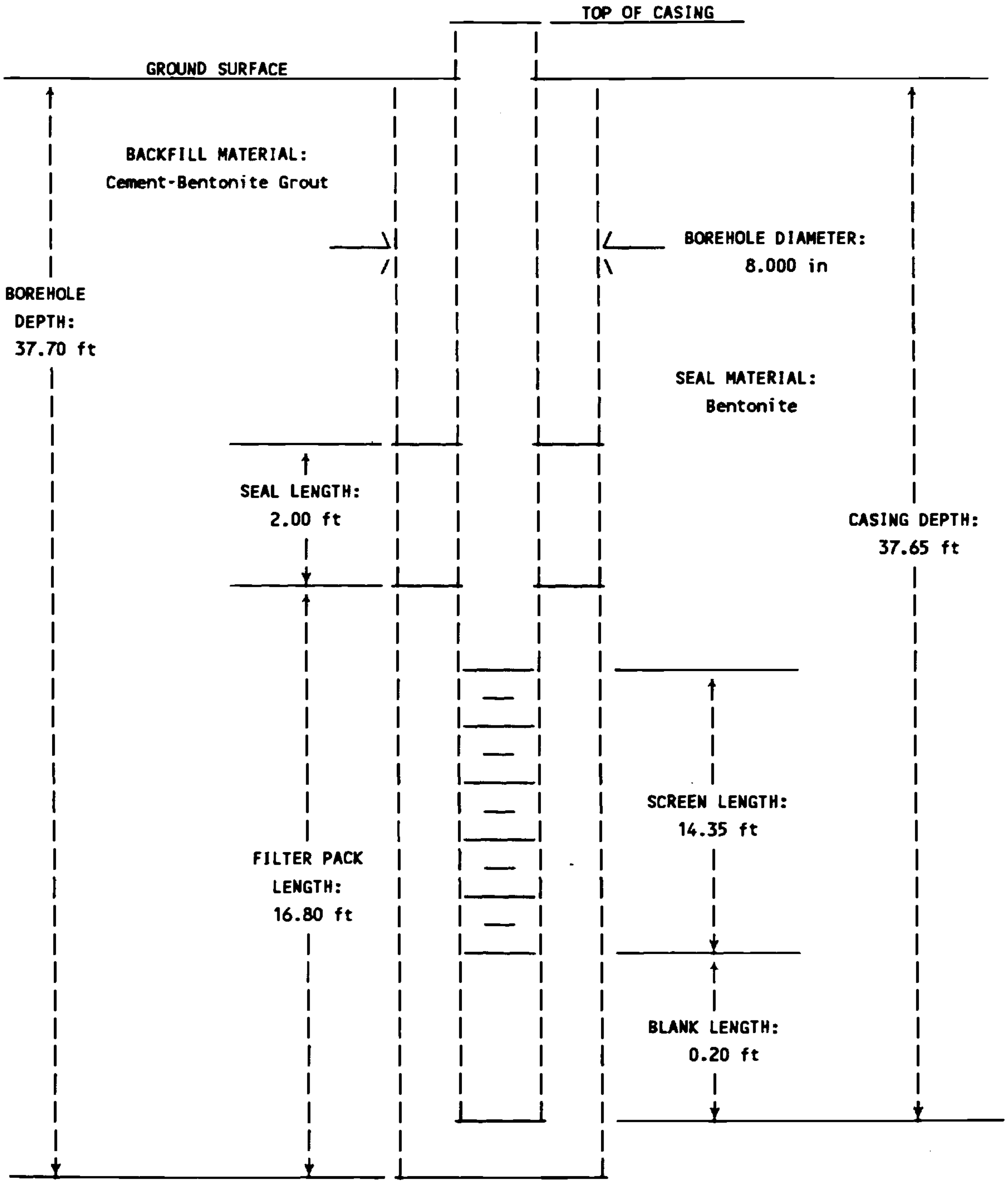
WELL COMPLETION LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB		9. INSTALLATION DATE: 3/28/90
		10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF04		11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation		12. SEAL END DEPTH: 20.90 ft
4. WELL NO.: LF04-02		13. MEAS. POINT ELEV.: 623.68 ft MSL
5. WELL OWNER: U.S. AIR FORCE		14. CASING DIAMETER: 2.00 in
6. WELL TYPE CLASS: MONITORING WELL		15. CASING MATERIAL: Schedule 40 PVC
7. FORMATION OF COMPLETION:		16. SCREEN BEGIN. DEPTH: 23.10 ft
8. LOCATION TYPE: WL		17. SCREEN SLOT SIZE: 0.02 in

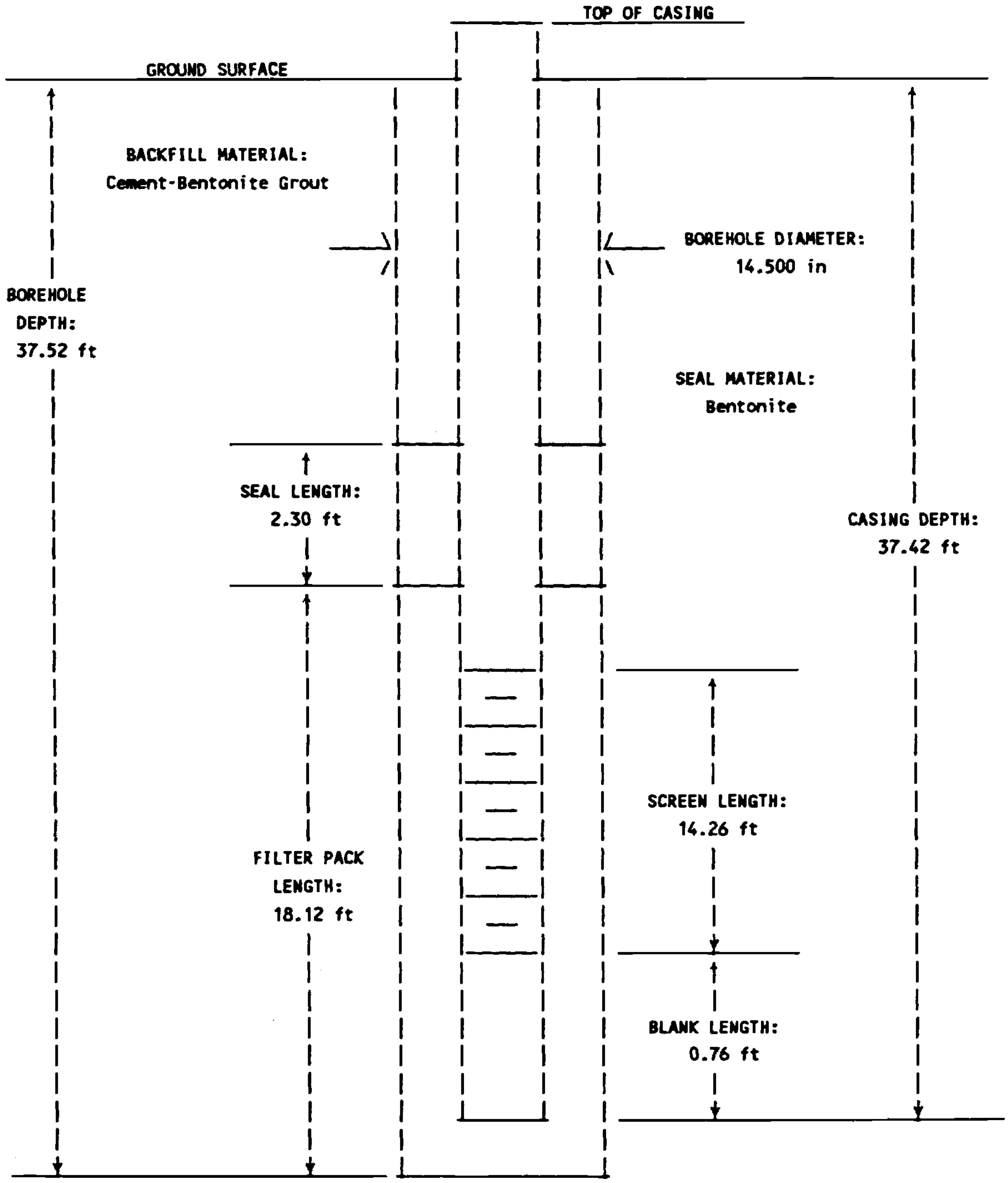
18. REMARKS: 1-10'x2"x0.02" Screen,3-10'x2" Risers,1-Cut piece (~0.4'),1-Locking Cap, 1-bottom Cap



FILTER PACK MATERIAL: 8-20 Silica Sand

WELL COMPLETION LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB		9. INSTALLATION DATE: 4/3/90
		10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF04		11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation		12. SEAL END DEPTH: 19.40 ft
4. WELL NO.: LF04-03		13. MEAS. POINT ELEV.: 623.25 ft MSL
5. WELL OWNER: U.S. AIR FORCE		14. CASING DIAMETER: 6.00 in
6. WELL TYPE CLASS: MONITORING WELL		15. CASING MATERIAL: Schedule 80 PVC
7. FORMATION OF COMPLETION:		16. SCREEN BEGIN. DEPTH: 22.40 ft
8. LOCATION TYPE: WL		17. SCREEN SLOT SIZE: 0.02 in

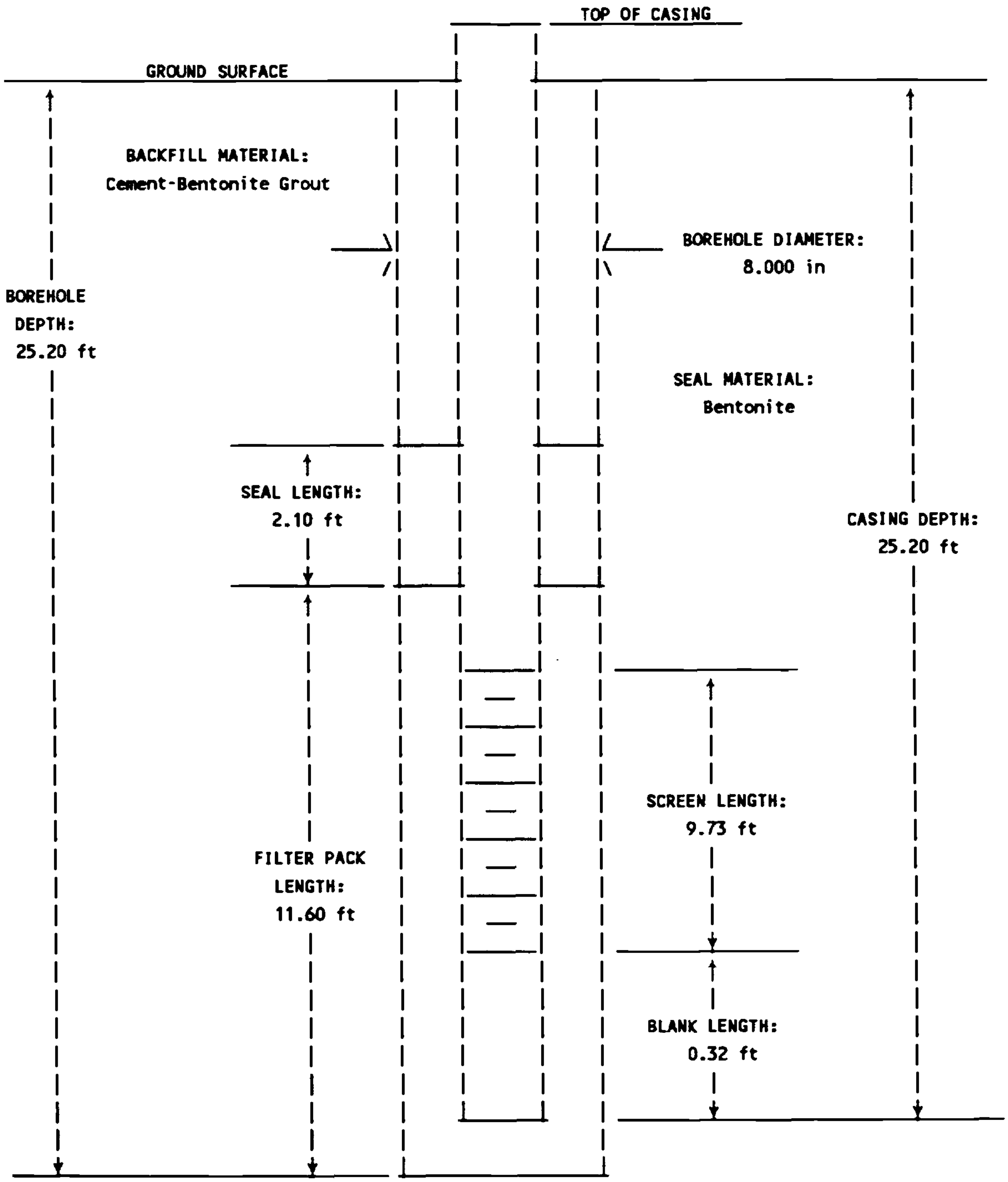
18. REMARKS: 1x10'x6" PVC 0.020 screen, 1x5'x6" screen, 2x10'x6" PVC riser, 1x5'x6" riser.



FILTER PACK MATERIAL: 8-20 Silica Sand

WELL COMPLETION LOG / RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB	9. INSTALLATION DATE: 3/20/90
	10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF04	11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation	12. SEAL END DEPTH: 13.20 ft
4. WELL NO.: LF04-04	13. MEAS. POINT ELEV.: 612.07 ft MSL
5. WELL OWNER: U.S. AIR FORCE	14. CASING DIAMETER: 2.00 in
6. WELL TYPE CLASS: MONITORING WELL	15. CASING MATERIAL: Schedule 40 PVC
7. FORMATION OF COMPLETION:	16. SCREEN BEGIN. DEPTH: 15.20 ft
8. LOCATION TYPE: WL	17. SCREEN SLOT SIZE: 0.02 in

18. REMARKS: Sounded Well after Completion, 25' BLS. * Cave-in from 25.2' - 24.8'



FILTER PACK MATERIAL: 8-20 Silica Sand

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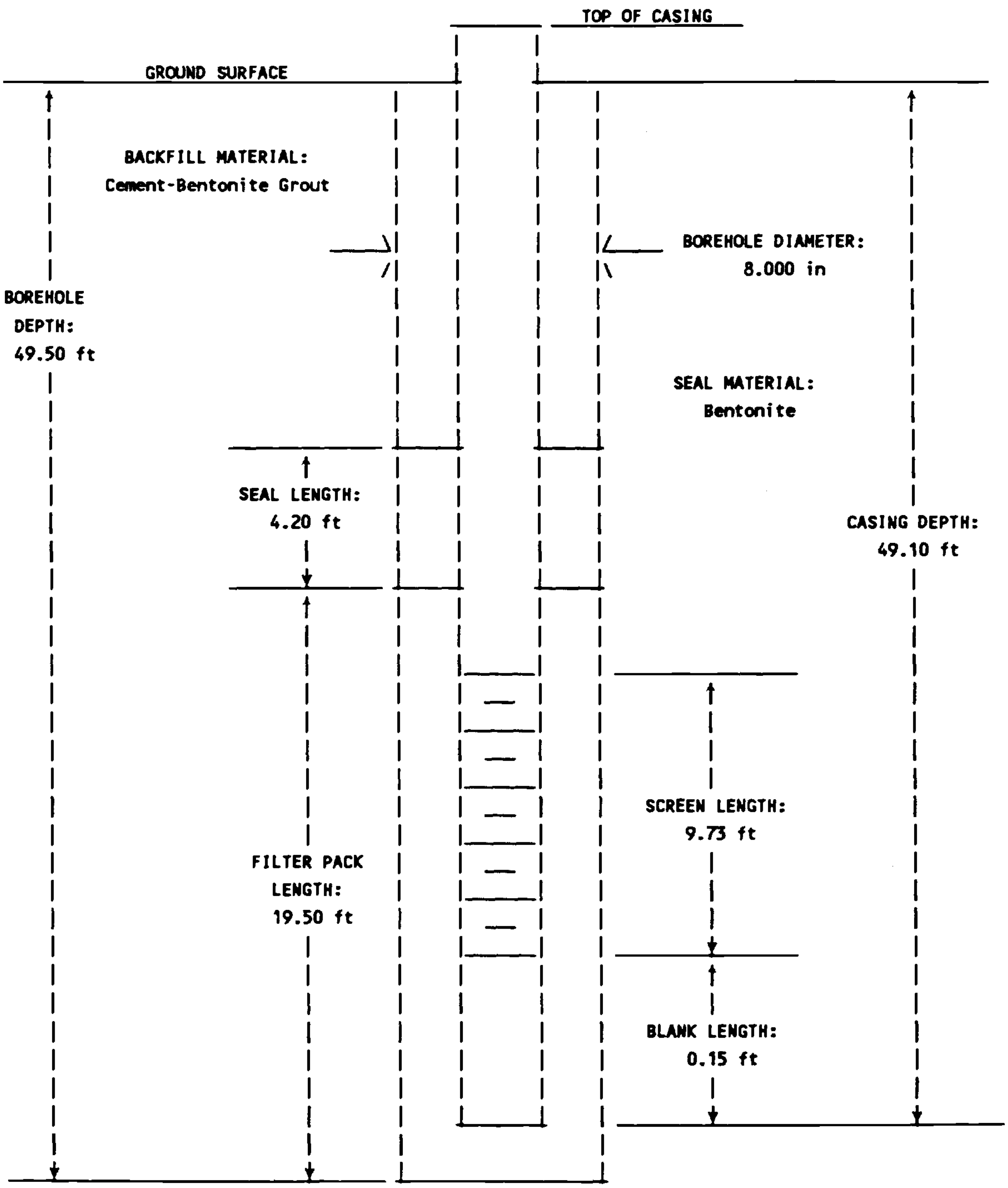
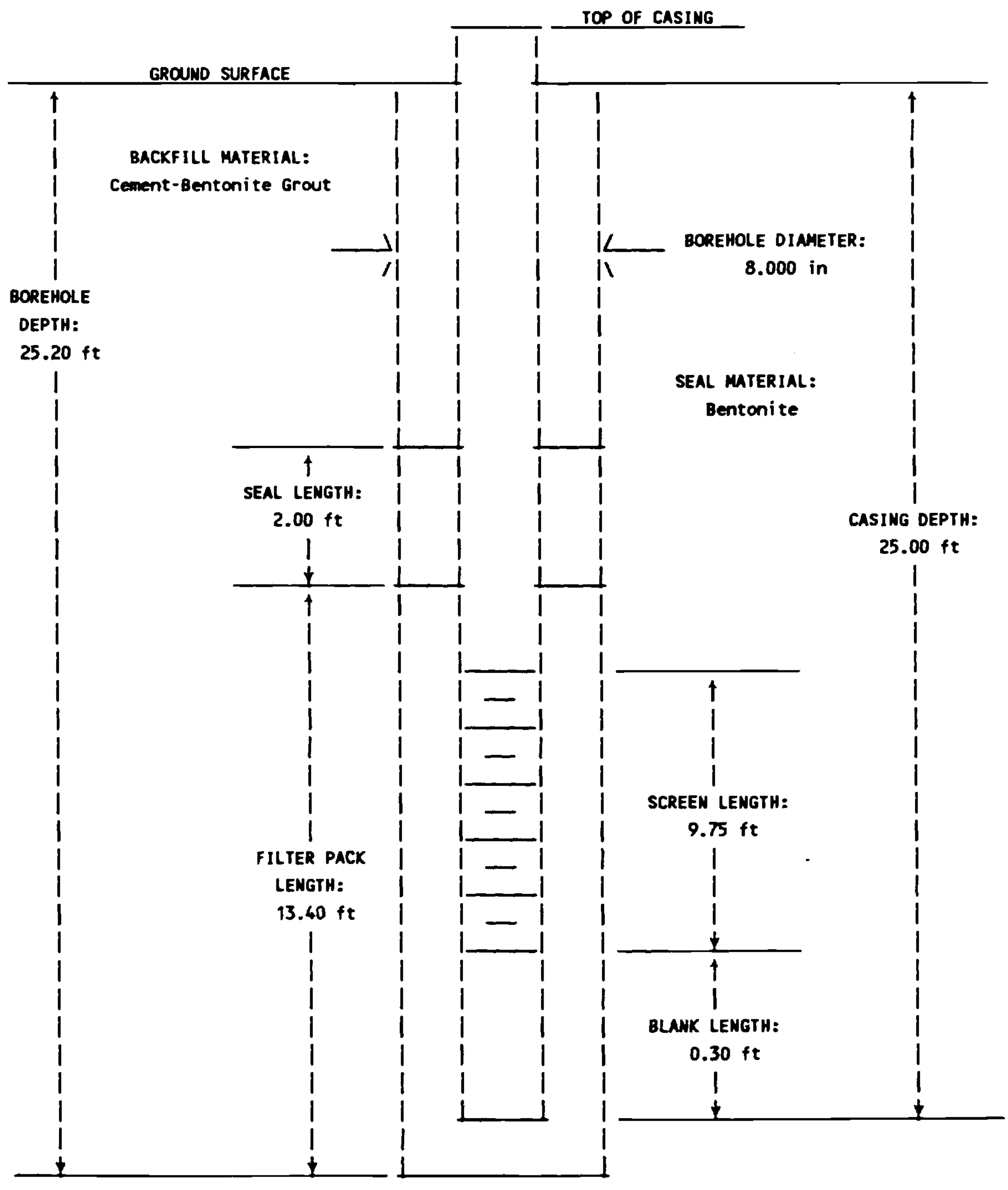
WELL COMPLETION LOG | RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB	9. INSTALLATION DATE: 4/2/90
	10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF04	11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation	12. SEAL END DEPTH: 30.00 ft
4. WELL NO.: LF04-10	13. MEAS. POINT ELEV.: 626.54 ft MSL
5. WELL OWNER: U.S. AIR FORCE	14. CASING DIAMETER: 2.00 in
6. WELL TYPE CLASS: MONITORING WELL	15. CASING MATERIAL: Schedule 40 PVC
7. FORMATION OF COMPLETION:	16. SCREEN BEGIN. DEPTH: 39.22 ft
8. LOCATION TYPE: WL	17. SCREEN SLOT SIZE: 0.02 in

18. REMARKS: 4x10'x2" Riser (-1.25), 1x2"x10' Screen (0.020 SL), 1x2"x0.2' Sed. Trap, 1 - Locking 2" topcap, Flush mount in cast iron vault - grout.



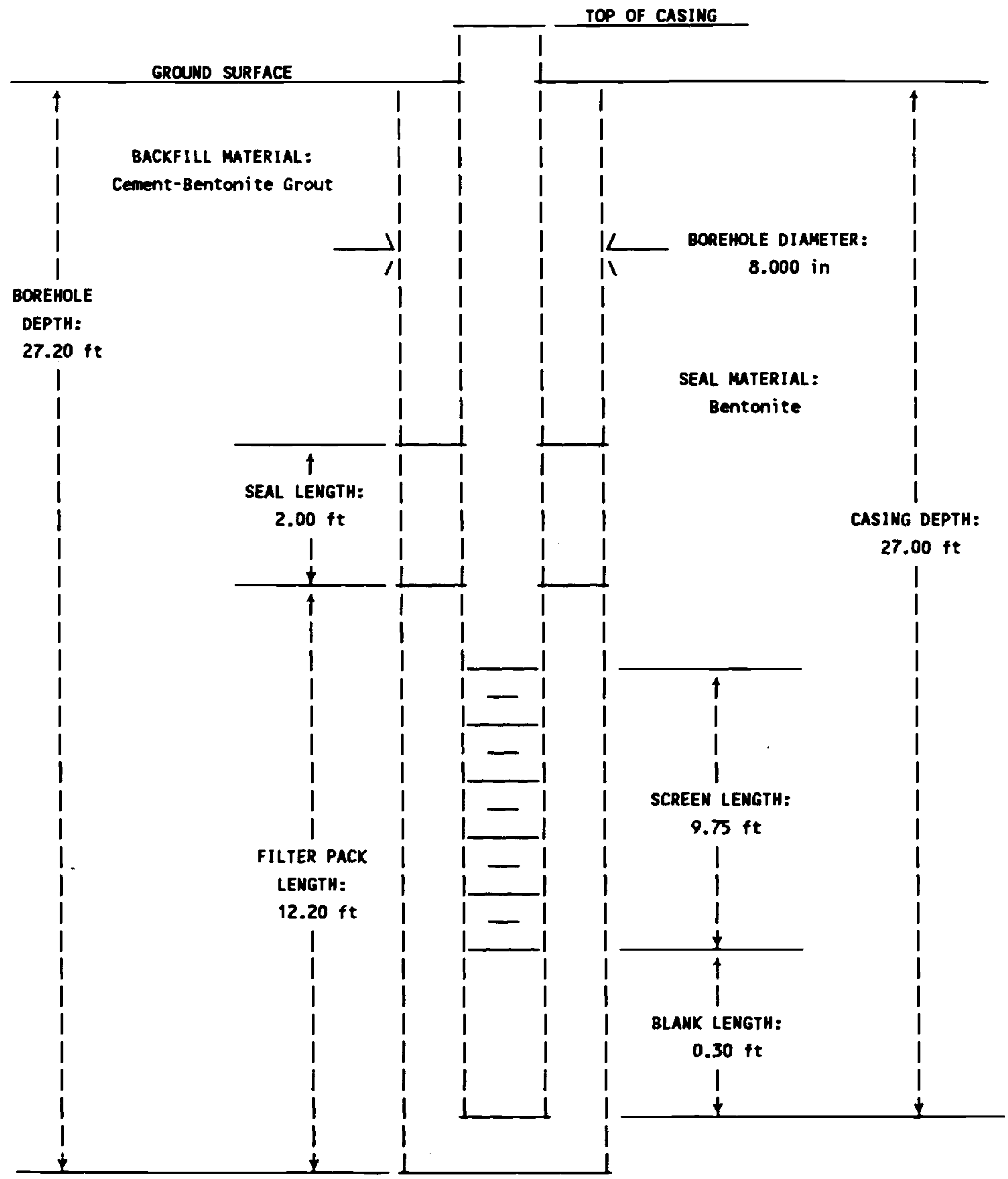
FILTER PACK MATERIAL: 8-20 Silica Sand

WELL COMPLETION LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB		9. INSTALLATION DATE: 3/22/90
		10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF05		11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation		12. SEAL END DEPTH: 11.80 ft
4. WELL NO.: LF05-01		13. MEAS. POINT ELEV.: 621.96 ft MSL
5. WELL OWNER: U.S. AIR FORCE		14. CASING DIAMETER: 2.00 in
6. WELL TYPE CLASS: MONITORING WELL		15. CASING MATERIAL: Schedule 40 PVC
7. FORMATION OF COMPLETION:		16. SCREEN BEGIN. DEPTH: 14.95 ft
8. LOCATION TYPE: WL		17. SCREEN SLOT SIZE: 0.02 in
18. REMARKS: 1-10'x2"x0.02" Screen, 2-10'x2" Risers, 1-0.2 Bottom, 1-Locking Cap		



FILTER PACK MATERIAL: 8-20 Silica Sand

WELL COMPLETION LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB		9. INSTALLATION DATE: 3/22/90
		10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF05		11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation		12. SEAL END DEPTH: 15.00 ft
4. WELL NO.: LF05-02		13. MEAS. POINT ELEV.: 622.69 ft MSL
5. WELL OWNER: U.S. AIR FORCE		14. CASING DIAMETER: 2.00 in
6. WELL TYPE CLASS: MONITORING WELL		15. CASING MATERIAL: Schedule 40 PVC
7. FORMATION OF COMPLETION:		16. SCREEN BEGIN. DEPTH: 16.95 ft
8. LOCATION TYPE: WL		17. SCREEN SLOT SIZE: 0.02 in
18. REMARKS: 1-10'x2"x0.02" Screen, 2-10'x2" Risers, 1-0.2 Bottom Trap, 1-Locking Cap		

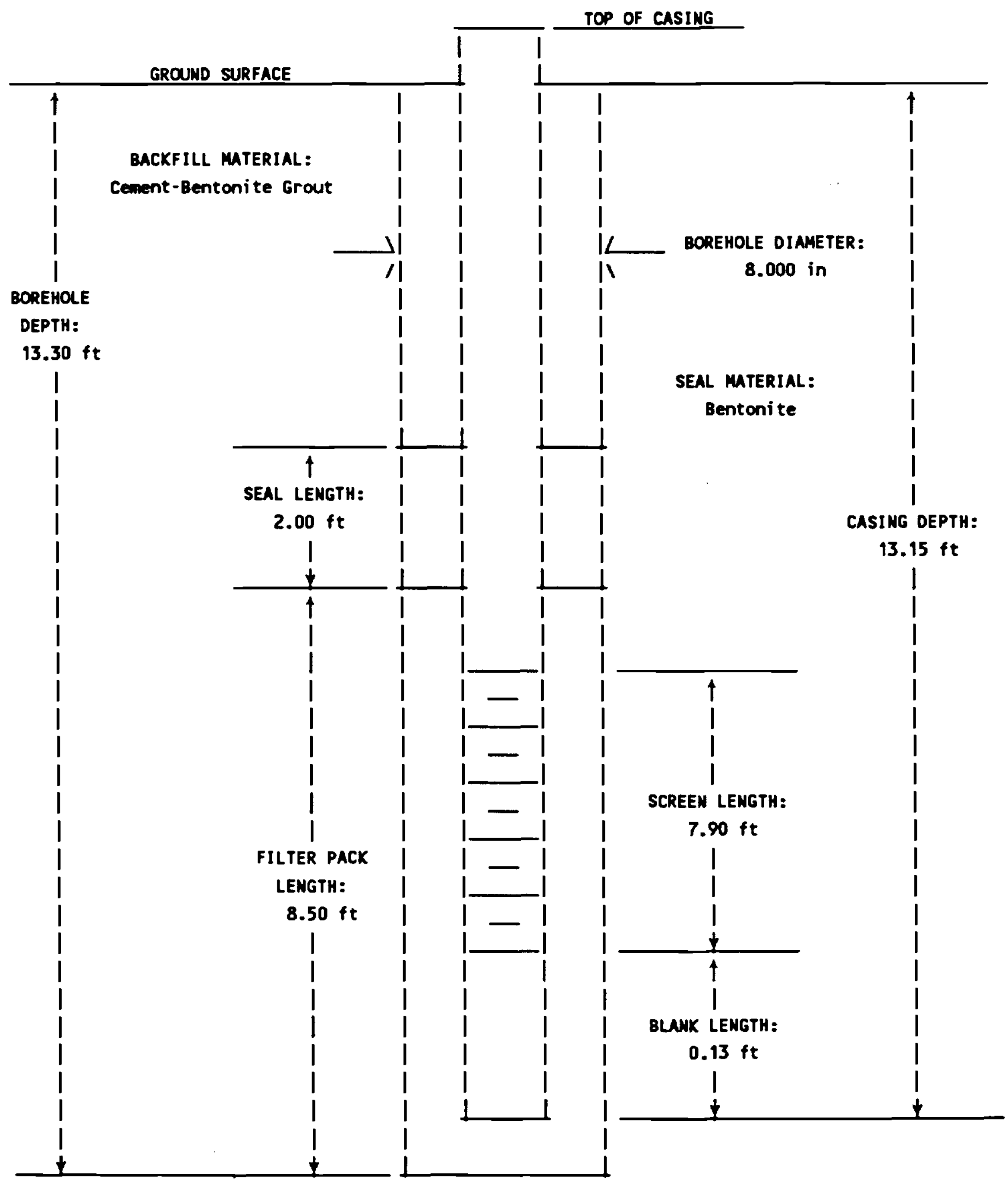


FILTER PACK MATERIAL: 8-20 Silica Sand

73 390

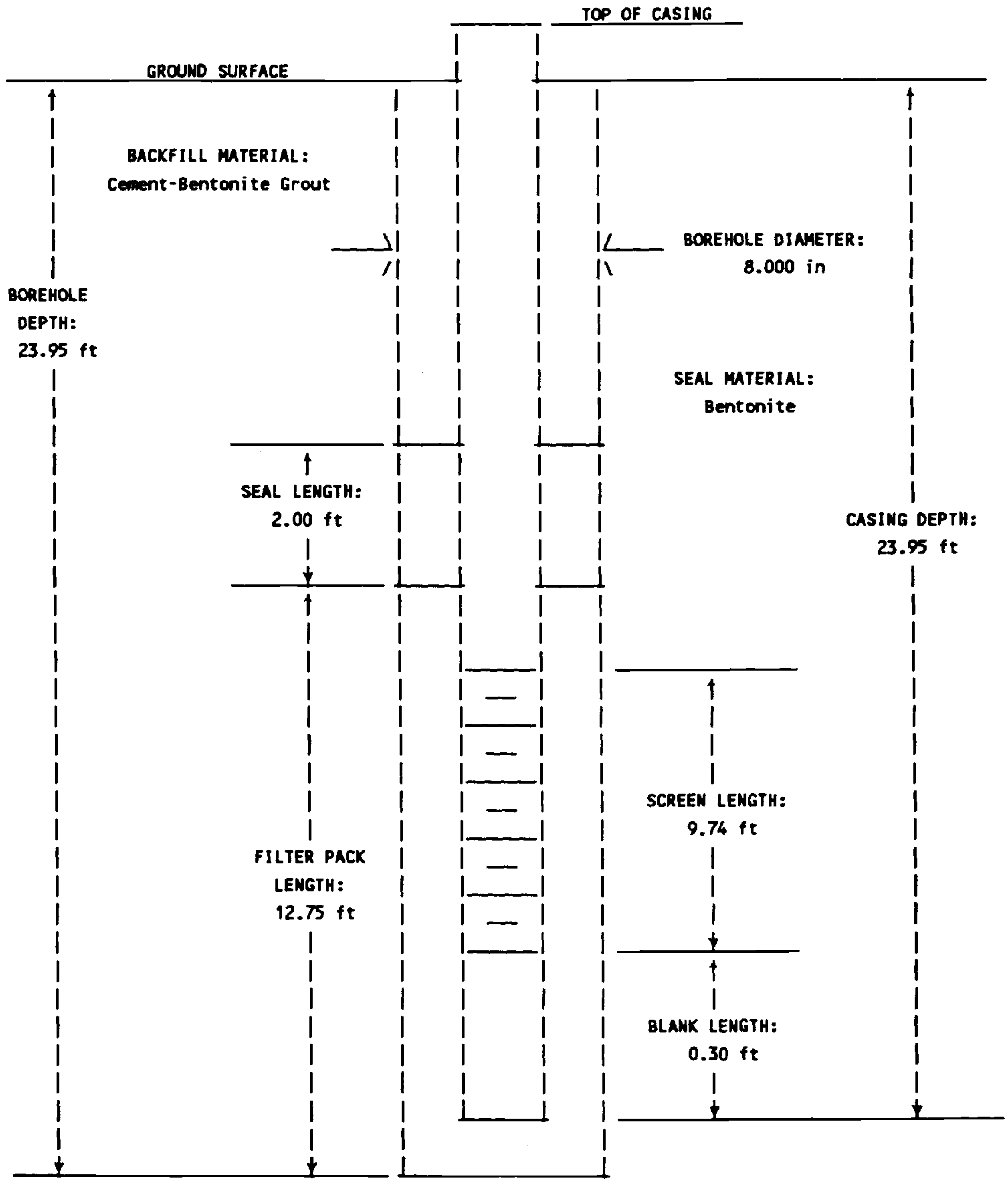
WELL COMPLETION LOG / RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB	9. INSTALLATION DATE: 4/2/90
	10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF05	11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation	12. SEAL END DEPTH: 4.80 ft
4. WELL NO.: LF05-14	13. MEAS. POINT ELEV.: 602.98 ft MSL
5. WELL OWNER: U.S. AIR FORCE	14. CASING DIAMETER: 2.00 in
6. WELL TYPE CLASS: MONITORING WELL	15. CASING MATERIAL: Schedule 40 PVC
7. FORMATION OF COMPLETION:	16. SCREEN BEGIN. DEPTH: 5.12 ft
8. LOCATION TYPE: WL	17. SCREEN SLOT SIZE: 0.02 in

18. REMARKS: 1x2"x5.0' Riser (-0.2'), 1x2"x10' Screen (-1.83'), 1x2"x0.13 Bottom cap, 1 Locking top, Flush Mount w/ cast-iron vault-grouted.



FILTER PACK MATERIAL: 8-20 Silica Sand

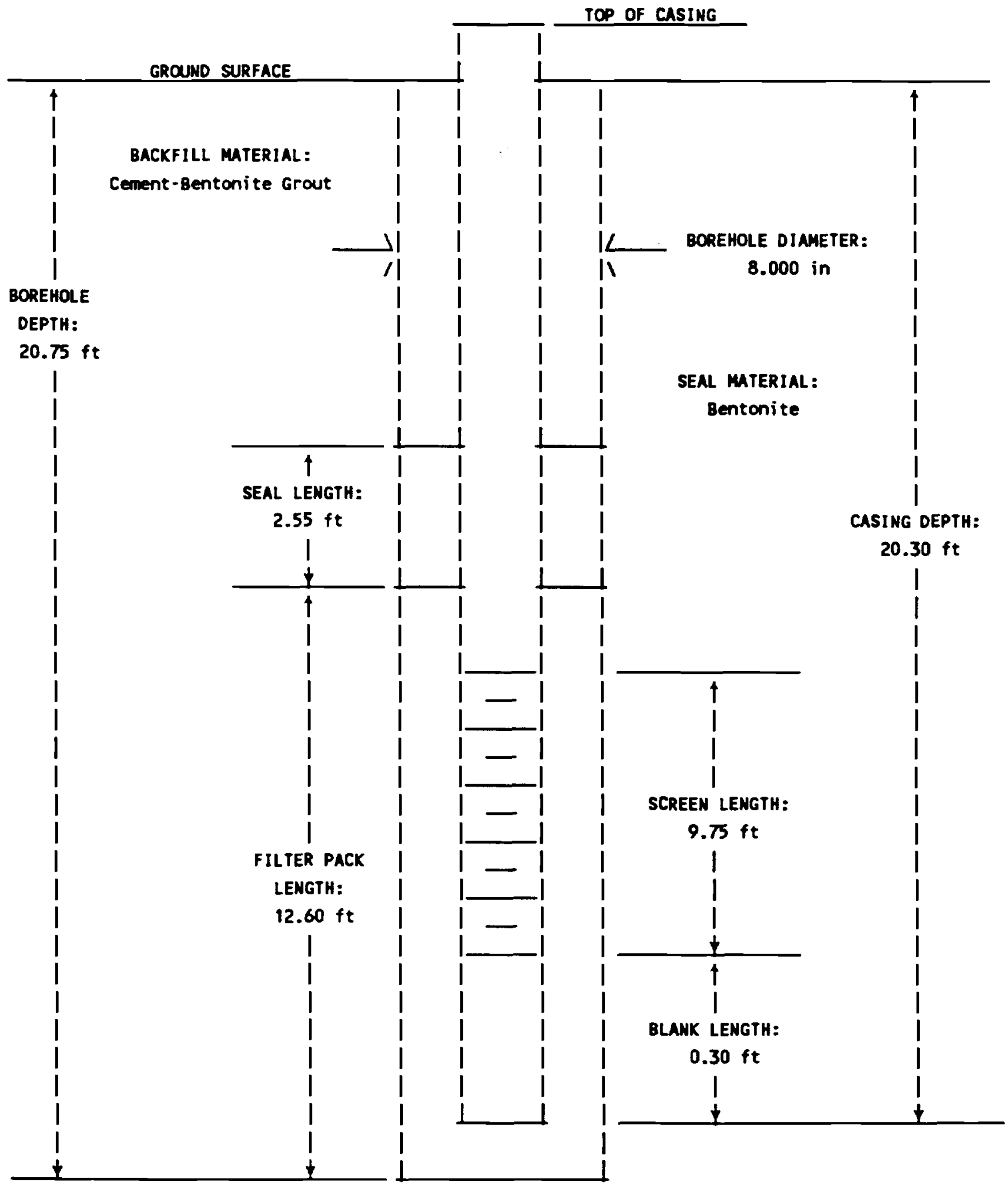
WELL COMPLETION LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB		9. INSTALLATION DATE: 3/21/90
		10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF05		11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation		12. SEAL END DEPTH: 11.60 ft
4. WELL NO.: LF05-18		13. MEAS. POINT ELEV.: 611.84 ft MSL
5. WELL OWNER: U.S. AIR FORCE		14. CASING DIAMETER: 2.00 in
6. WELL TYPE CLASS: MONITORING WELL		15. CASING MATERIAL: Schedule 40 PVC
7. FORMATION OF COMPLETION:		16. SCREEN BEGIN. DEPTH: 13.90 ft
8. LOCATION TYPE: WL		17. SCREEN SLOT SIZE: 0.02 in
18. REMARKS:		



FILTER PACK MATERIAL: 8-20 Silica Sand

WELL COMPLETION LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB		9. INSTALLATION DATE: 3/21/90
		10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF05		11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation		12. SEAL END DEPTH: 8.15 ft
4. WELL NO.: LF05-19		13. MEAS. POINT ELEV.: 606.08 ft MSL
5. WELL OWNER: U.S. AIR FORCE		14. CASING DIAMETER: 2.00 in
6. WELL TYPE CLASS: MONITORING WELL		15. CASING MATERIAL: Schedule 40 PVC
7. FORMATION OF COMPLETION:		16. SCREEN BEGIN. DEPTH: 10.25 ft
8. LOCATION TYPE: WL		17. SCREEN SLOT SIZE: 0.02 in

18. REMARKS: Casing is actually 19.9' but sits 0.4' below land surface; 1-10'x2" Screen, 1-10' Riser, 1-0.2' Bottom Trap, 1-Locking Cap



FILTER PACK MATERIAL: 8-20 Silica Sand

APPENDIX C

Well Development Information

(Previous Well Development Information may be found in CH2M Hill (1984), Radian (1986), and Radian (1989))

WELL DEVELOPMENT DATA - CARSWELL AFB

Location ID	Log Date	Cumulative Gallons	Cumulative Bore Volumes	Specific Conductance (micromhos/cm)	pH	Temp_F	Comments	Method
LF04-01	8/4/90	4.00		860	6.95	68.88		Bailmaster 36" Teflon Fluoroware Bailer
		10.00		840	6.88	67.82		
		17.00		850	6.88	68.00		
		23.00		860	6.87	68.36		
		28.00		850	6.88	68.18		
		35.00		860	6.83	68.18		
		43.00		860	6.86	68.54	Full bailer every pull, not getting sed. off bottom	
		52.00	3.08	860	6.89	68.18		
LF04-02	8/4/90	5.00		860	6.91	67.28		Brainard Killman 1 1/2" Hand Pump
		15.00		850	6.94	67.64		
		20.00		840	6.91	67.10		
		30.00		840	6.91	67.64	20 Minute stop to repair pump;pulled pump 4' off bottom to keep sed. from clogging	
		38.00		840	6.91	68.72		
		48.00		840	6.91	68.36		
		53.00		840	6.95	68.00	Go to 2nd 55 gal. barrel	
		63.00		850	6.94	68.00		
		82.00		840	6.95	68.36		
		87.00	4.89	840	6.94	68.36		
LF04-03	12/4/90	8.00		750	6.53	64.04		Brainard Killman 1 1/2" Hand Pump
		34.00		810	6.74	67.46	Break to check on crew	
		68.00		820	6.63	68.90		
		90.00		920	6.65	69.44		
		115.00		830	6.68	69.08	Break to check on crew	
		152.00		820	6.63	69.80		
		174.00		840	6.64	69.08		
		195.00	3.72	850	6.76	68.72		
LF04-04	10/4/90	4.00		840	6.77	65.12	Full bailer every pull	Bailmaster 36" Teflon Fluoroware Bailer
		15.00		850	6.79	64.94		

WELL DEVELOPMENT DATA - CARSWELL AFB

Location ID	Log Date	Cumulative Gallons	Cumulative Bore Volumes	Specific Conductance (micromhos/cm)	pH	Temp_F	Comments	Method
		23.00		860	6.81	64.58		
		31.00		860	6.72	64.76		
		38.00		850	6.73	64.76		
		46.00		860	6.75	64.94		
		55.00	3.71	850	6.77	64.58		
LF04-10	13/4/90	3.00		730	7.40	67.10		Bailmaster 36" Teflon Fluoroware Bailer
		23.00		930	6.97	68.00		
		32.00		940	6.93	67.82		
		43.00		950	6.90	67.64		
		49.00		950	6.90	67.64		
		55.00		940	6.89	67.64		
		60.00		940	6.91	67.28		
		70.00		950	6.87	67.64		
		82.00	3.25	940	6.86	67.82		
LF05-01	8/4/90	3.00		1440	6.78	66.92		Bailmaster 36" Teflon Fluoroware Bailer
		10.00		1170	6.83	67.10		
		18.00		1370	6.77	67.10	Dropped bailer in hole; Delay	
		24.00		1080	6.80	67.64		
		29.00		1020	6.85	67.64		
		40.00	4.56	960	6.81	68.00		
LF05-02	7/4/90	4.00		1110	6.58	66.20		Brainard Killman 1 1/2" Hand Pump
		10.00		1120	6.68	66.56		
		25.00		1120	6.61	66.56	Pumping at approx. 5 gpm w/ no draw	
		32.00		1120	6.54	66.56	5 min. down time; visitor at site	
		43.00		1120	6.63	64.94		
		49.00		1110	6.63	64.94		
		53.00	5.96	1120	6.69	64.76		
LF05-14	9/4/90	5.00		920	6.64	63.50	Temp taken after 2 min = low	Bailmaster 36" Teflon Fluoroware Bailer
		10.00		910	7.24	63.32	Orig Temp ok	
		16.00		910	6.64	62.60	Some pulls only 85% full	
		22.00		910	6.63	62.60		
		26.00		910	6.63	62.60		

WELL DEVELOPMENT DATA - CARSWELL AFB

Location ID	Log Date	Cumulative Gallons	Cumulative Bore Volumes	Specific Conductance (micromhos/cm)	pH	Temp_F	Comments	Method
		31.00	5.28	910	6.65	62.60		
LF05-18	9/4/90	4.00		930	6.71	65.48		Bailmaster 36" Teflon Fluoroware Bailer
		10.00		920	6.70	65.84		
		18.00		920	6.71	65.66	Full bailer every pull	
		26.00		920	6.67	66.02		
		33.00		910	6.67	65.84		
		38.00	4.75	920	6.65	66.02		
LF05-19	10/4/90	3.00		890	6.68	64.40	Full bailer each pull	Bailmaster 36" Teflon Fluoroware Bailer
		12.00		910	6.71	64.58		
		21.00		920	6.71	64.40		
		29.00		920	6.76	64.22		
		36.00		900	6.71	64.40	Rechecked probe w/ 4.0 std = 3.99	
		45.00	4.41	900	6.76	64.22		

APPENDIX D

Water Quality Sampling Records

(Previous Water Quality Sampling Records may be found in CH2M Hill (1984), Radian (1986), and Radian (1989))

GROUND WATER QUALITY SAMPLING RECORD

INSTALLATION ID CSWL LOG DATE 4-25-90 LOG TIME 0830

LOCATION ID LF04-01 LOT CONTROL NO.

SAMPLE TYPE N&MS&MSD SAMPLE ID SAMPLE DEPTH (FT.) 29.45 BTC

INITIAL GROUNDWATER DEPTH (FT) 29.45 BTC T.D = 41.4' BTC (SOUNDED) 11.95·0.17 = 2.03·3 = 6.09g FOR 3 WET CASINGS

SAMPLING PERIOD: START 0950 COMPLETE 1115

SAMPLING METHOD B LOGGER CODE RAON

LAB CODE RAON DATE SENT 4-25-90

PRESERVATION METHOD 4°C; HNO_3 - METALS

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.88	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	962	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0

TOTAL UNFILTERED ALK = 565 mg/L TOTAL FILTERED ALK = 364 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP (°C)	COMMENTS
0910	0.0	0.0	-	-	-	START PUMPING
0915	1.0		6.81	950	70°F	ORANGE/BROWN MOD. TURBID
0918	2.0		6.89	960	70°F	"
0924	3.0		6.97	956	70°F	"
0930	4.0		6.93	958	70.5°F	"
0936	5.0		6.87	959	70.5°F	"
0943	7.0		6.88	962	70.5°F	"

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK

R - REPLICATE TB - TRIP BLANK

S - SPIKE LB - LAB BLANK

K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP

B - BAILER AL - AIR-LIFT SAMPLER

PP - PERISTALTIC PUMP BP - BLADDER PUMP

SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD 78 312

INSTALLATION ID CSWL LOG DATE 4-27-90 LOG TIME 1120
LOCATION ID LF04-02 LOT CONTROL NO. ______
SAMPLE TYPE N SAMPLE ID ______ SAMPLE DEPTH (FT.) ______

TOT. DEPTH = 39.65' BTC (SOUNDED) 12.57 ft, 6.41g = 3 VOLUMES
INITIAL GROUNDWATER DEPTH (FT) 27.04' BTC
SAMPLING PERIOD: START 1157 COMPLETE 1210
SAMPLING METHOD B LOGGER CODE RADN
LAB CODE RADN DATE SENT 4-27-90
PRESERVATION METHOD 4°C, HNO_3 - METALS
COMMENTS OPO4 COLLECTED FOLLOWING WEEK

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.86	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	833	1
REDOX POTENTIAL	Eh	mvolts		
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK. = 0
TOTAL UNFILTERED ALK = 412 mg/L TOTAL FILTERED ALK = 301

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1138	0.0	0.0	-	-	-	START PUMPING
1140	1.0		6.75	843	70.0°F	LT. BROWN SLIGHTLY TURBID
1143	1.5		6.78	833	70.5°F	"
1146	3.0		6.81	834	70.5°F	"
1149	4.0		6.83	831	70.8°F	"
1150	5.0		6.83	830	70.7°F	"
1156	7.0		6.86	833	71.0°F	ALMOST CLEAR

SAMPLES TYPES: (WSACODE)
D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)
G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

73 313

INSTALLATION ID CSWL LOG DATE 4/17/90 LOG TIME 0752

LOCATION ID LF04-04 LOT CONTROL NO. ______

SAMPLE TYPE N SAMPLE ID ______ SAMPLE DEPTH (FT.) 17.43 BTC

INITIAL GROUNDWATER DEPTH (FT) 17.43 (TOC) h= 10.07' 3V = 5.14 gal

SAMPLING PERIOD: START 0900 COMPLETE 0933

SAMPLING METHOD B LOGGER CODE RAON

LAB CODE RAON DATE SENT 4/17/90

PRESERVATION METHOD 4°C; HNO_3 IN METALS

COMMENTS ______

FINAL PARAMETER MEASUREMENTS: W.L. = 17.47' BTOC AFTER SAMPLING

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.82	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	799	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C	18.5	0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

Phenolpthalein (P) Alkalinity = 0.0
Total Alkalinity = 549 x 1.0 = 549 mg/L (352 mg/L FILTERED)

TIME	TOTAL VOLUME WITHDRAWN (WETTED CASING) (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
8:25	0.0	0.0	-	-	-	START PUMPING
8:35	2	1.17	6.66	790	18.5	orange-tan, mod. turbid
8:40	4	2.34	6.46	765	18.7	" "
8:43	5.5	3.22	6.82	799	18.5	" "

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

73 314

INSTALLATION ID CSWL LOG DATE 4/17/90 LOG TIME 1016

LOCATION ID LF04-10 LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 31.48 BTC

INITIAL GROUNDWATER DEPTH (FT) 31.48 (TOC) 17.12 x.17 = 2.91 gal x 3 = 8.73

SAMPLING PERIOD: START 1110 COMPLETE 1145

SAMPLING METHOD B LOGGER CODE RAON

LAB CODE DATE SENT 4/17/90

PRESERVATION METHOD 4° C ; HNO_3 (pH < 2) WITH METALS

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.06	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	850	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C	19.7	0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

Phenopthalein (P) Alkalinity = 0.0

Total alkalinity non-filtered = 370 mg/L Filtered 336 mg/L

TIME	TOTAL VOLUME WITHDRAWN (wetted casing) (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
10:25	0.0	0.0	-	-	-	START PUMPING
1036	2.0	0.69	5.95	968	18.5	purge water clear, no odor
1047	4.0	1.37	5.45	857	18.5	orange/brown, slightly turbid
1054	7.0	2.41	5.99	820	19.8	"
1100	8.0	2.75	6.15	840	19.5	"
1107	9.0	3.09	6.06	850	19.7	light tan, slightly turbid

SAMPLES TYPES: (WSACODE)

- D - DUPLICATE
- R - REPLICATE
- S - SPIKE
- K - KNOWN
- FB - FIELD BLANK
- TB - TRIP BLANK
- LB - LAB BLANK
- N - NORMAL

SAMPLE METHODS: (WSMCODE)

- G - GRAB
- B - BAILER
- PP - PERISTALIC PUMP
- SL - SUCTION LIFT PUMP
- SP - SUBMERSIBLE PUMP
- AL - AIR-LIFT SAMPLER
- BP - BLADDER PUMP

GROUND WATER QUALITY SAMPLING RECORD 73 315

INSTALLATION ID CSWL LOG DATE 5/7/90 LOG TIME 1530

LOCATION ID LF04-4A LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 8.10 BTC

INITIAL GROUNDWATER DEPTH (FT) ≈ 8.10' BTC T.D. = 24.85' BTC (SOUNDED) 8.54 gal. = 3 wetted casing volumes

SAMPLING PERIOD: START 1541 COMPLETE 1600

SAMPLING METHOD B LOGGER CODE RADN

LAB CODE RADN DATE SENT 5/7/90

PRESERVATION METHOD 4°C; HNO_3 - METALS

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.96	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	668	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0.0

TOTAL UNFILTERED ALK = 285 TOTAL FILTERED ALK = 268

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP (°C)	COMMENTS
1531	0.0	0.0	-	-	-	START PUMPING
1535	2.5		6.93	672	66.1°F	LT. TAN SLIGHTLY TURBID
1537	4.0		6.99	664	65.8°F	"
1539	5.0		6.97	661	65.6°F	"
1541	6.5		6.94	668	65.8°F	"
1544	8.5		6.96	668	66.0°F	"
1545	9.0		—	—	—	END PURGE

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALTIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD 72 316

INSTALLATION ID CSWL LOG DATE 5/7/90 LOG TIME 1355

LOCATION ID 2F04-4B LOT CONTROL NO.

SAMPLE TYPE N & EB SAMPLE ID SAMPLE DEPTH (FT.) 15.02 BTC

INITIAL GROUNDWATER DEPTH (FT) 15.02 BTC T.D. = 25.44' BTC (SOUNDED) 5.31 gal = 3 wetted casing vo

SAMPLING PERIOD: START 1423 COMPLETE 1450 (N)

SAMPLING METHOD B LOGGER CODE RAON

LAB CODE RAON DATE SENT 5/7/90

PRESERVATION METHOD 4°C · HNO$_3$ - METALS

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.74	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	533	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0.0

TOTAL UNFILTERED ALK = 531 TOTAL FILTERED ALK. = 286 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1408	0.0	0.0	-	-	-	START PUMPING
1411	1.0		6.58	550	65.0°F	SLIGHTLY CLOUDY
1414	2.0		6.62	532	64.2°F	"
1416	3.0		6.67	533	63.1°F	"
1418	4.0		6.70	521	64.0°F	ALMOST CLEAR SLIGHTLY CL
1420	5.5		6.72	529	63.4°F	"
1422	7.0		6.74	533	63.0°F	"
		EQUIPMENT BLANK				
1455			6.20	0.01	82.5°F	CLEAR
		TOTAL	ALKALINITY =		0.0 mg/L	

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

73 317

INSTALLATION ID CSWL LOG DATE 4-24-90 LOG TIME 1500
LOCATION ID LF04-4C LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 17.10' BTC

INITIAL GROUNDWATER DEPTH (FT) 17.10 BTC TD=20.05' BTC (SOUNDED) 1.8bg/wetted casing volume 5.5bg to purge
SAMPLING PERIOD: START 1533 COMPLETE 1555
SAMPLING METHOD B LOGGER CODE RADN
LAB CODE RADN DATE SENT 4-24-90
PRESERVATION METHOD 4°C, HNO_3 - METALS
COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.40	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	1264	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0
TOTAL UNFILTERED ALK = 523 mg/L TOTAL FILTERED ALK = 452 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1520	0.0	0.0	-	-	-	START PUMPING
1522	1.0		6.27	1265	69°F	WATER CLEAR
1524	2.0		6.36	1262	69°F	LT. BROWN, SLIGHTLY TURBID
1526	3.0		6.33	1257	68.5°F	"
1528	4.0		6.35	1263	69°F	"
1530	5.0		6.39	1263	69°F	"
1533	6.0		6.40	1264	69°F	ORANGE/BROWN, SLIGHTLY CLOUDY

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

INSTALLATION ID CSWL LOG DATE 5/7/90 LOG TIME 1230
LOCATION ID LF04-4D LOT CONTROL NO.
SAMPLE TYPE N & AG SAMPLE ID SAMPLE DEPTH (FT.) 17.85 BTC

INITIAL GROUNDWATER DEPTH (FT) 17.85 BTC T.D. = 27.77 BTC (SOUNDED) 5.06 gal. = 3 wetted casing vol
SAMPLING PERIOD: START 1307 COMPLETE 1321
SAMPLING METHOD B LOGGER CODE RAON
LAB CODE RAON DATE SENT 5/7/90
PRESERVATION METHOD 4°C HNO$_3$-METALS
COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.81	0.6
SPECIFIC CONDUCTANCE	SC	µmhos/cm	843	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0.0
TOTAL UNFILTERED ALK = 589 TOTAL FILTERED ALK = 570 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1254	0.0	0.0	-	-	-	START PUMPING
1256	1.0		6.79	905	69.8°F	CLEAR
1301	2.5		6.80	845	70.0°F	LT. BROWN SLIGHTLY TO MOD.
1303	4.0		6.81	845	69.5°F	LT. ORANGE/BROWN "
1305	5.0		6.82	841	69.5°F	"
1307	6.0		6.81	843	69.5°F	"

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALTIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

INSTALLATION ID CSWL LOG DATE 5/7/90 LOG TIME 1049
LOCATION ID LF04-4E LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 21.31 BTC

INITIAL GROUNDWATER DEPTH (FT) 21.31 BTC T.D. = 30.85 BTC (SOUNDED) 4.87 gal. = 3 wetted casing volum
SAMPLING PERIOD: START 1118 COMPLETE 1127
SAMPLING METHOD B LOGGER CODE RAON
LAB CODE RAON DATE SENT 5-7-90
PRESERVATION METHOD 4°C. HNO_3 - METALS
COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.75	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	786	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0
TOTAL UNFILTERED ALK = 349 mg/L TOTAL FILTERED ALK = 339 mg/L.

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1105	0.0	0.0	-	-	-	START PUMPING
1109	1.0		6.64	784	70.0°F	ALMOST CLEAR, SLIGHT CLOUDINE
1112	2.5		6.68	786	70.5°F	"
1115	3.5		6.70	787	70.8°F	"
1118	5.0		6.75	786	70.5°F	"

SAMPLES TYPES: (WSACODE)
D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)
G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD 73 320

INSTALLATION ID CSWL LOG DATE 5/7/90 LOG TIME 0915
LOCATION ID LF04-4F LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 26.96 BTC

INITIAL GROUNDWATER DEPTH (FT) 26.96 BTC T.D. = 37.3' BTC (SOUNDED) 5.27 gal = 3 wetted casing
SAMPLING PERIOD: START 1012 COMPLETE 1025
SAMPLING METHOD B LOGGER CODE RADN
LAB CODE RADN DATE SENT 5/7/90
PRESERVATION METHOD 4°C - HNO_3 - METALS
COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.80	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	810	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0
TOTAL UNFILTERED ALK = 452 mg/L TOTAL FILTERED ALK = 345 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
0951	0.0	0.0	-	-	-	START PUMPING
0955	1.0		6.78	832	69.5°F	ALMOST CLEAR SLIGHTLY CLOUDY
0959	2.0		6.81	795	69.2°F	"
1005	3.5		6.80	802	69.5°F	"
1008	5.0		6.83	804	69.5°F	"
1010	6.0		6.80	810	69.5°F	LT. TAN, SLIGHTLY TURBID

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALTIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

73 321

INSTALLATION ID CSWL LOG DATE 4-27-90 LOG TIME 0900

LOCATION ID LF04-4G LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 24.38 BTC

T.D. = 33.5 BTC (SOUNDED)

9.12·0.17=1.55·3=4.65g to purge

INITIAL GROUNDWATER DEPTH (FT) 24.38 BTC

SAMPLING PERIOD: START 0944 COMPLETE 1013

SAMPLING METHOD B LOGGER CODE RAON

LAB CODE RAON DATE SENT 4-27-90

PRESERVATION METHOD 4°C; HNO_3 - METALS

COMMENTS oPO4 COLLECTED AT LATER DATE

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.98	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	845	1
REDOX POTENTIAL	Eh	mvolts		
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0

TOTAL UNFILTERED ALK = 630 mg/L TOTAL FILTERED ALK = 358 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP (°C)	COMMENTS
0925	0.0	0.0	-	-	-	START PUMPING
0927	1.0		6.92	826	68.0°F	ALMOST CLEAR, SLIGHTLY CLOUDY
0933	2.0		6.92	843	68°F	LT. BROWN, SLIGHTLY TURBID
0935	3.0		6.94	842	68.0°F	"
0937	3.5		6.97	841	67.5°F	"
0938	4.0		6.97	842	67.5°F	"
0943	5.0		6.98	845	67.5°F	"

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD 73 322

PAGE 1 OF 2

INSTALLATION ID CSWL LOG DATE 4-27-90 LOG TIME 1020
LOCATION ID LF04-4H LOT CONTROL NO. ____
SAMPLE TYPE N SAMPLE ID ____ SAMPLE DEPTH (FT.) ____

INITIAL GROUNDWATER DEPTH (FT) 17.72 BTC TD=31.0' BTC 13.28·0.17=2.26·3=6.78 g. to a
SAMPLING PERIOD: START 1052 COMPLETE 1102
SAMPLING METHOD B LOGGER CODE RADN
LAB CODE RADN DATE SENT 4-27-90
PRESERVATION METHOD 4°C · HNO_3 – METALS
COMMENTS OPO4 COLLECTED AT LATER DATE

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.99	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	878	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0
TOTAL UNFILTERED ALK = 387 MG/L TOTAL FILTERED ALK = 371 MG/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1035	0.0	0.0	-	-	-	START PUMPING
1039	1.0		6.87	852	66.0°F	ALMOST CLEAR
1041	2.0		6.96	882	66.0°F	" , ROOTLETS
1044	3.5		6.97	885	65.5°F	"
1045	4.5		6.98	884	66.0°F	" , ROOTLETS IN WATER
1047	6.0		6.97	877	65.5°F	ALMOST CLEAR
1050	7.0		6.99	878	65.5°F	" , ROOTLETS

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD 73 323

INSTALLATION ID CSWL LOG DATE 4-25-90 LOG TIME 1400
LOCATION ID LF05-01 LOT CONTROL NO.
SAMPLE TYPE N & D SAMPLE ID SAMPLE DEPTH (FT.) 17.25 BTC

T.D. = 27.55' BTC (SOUNDED); 10.3·0.17 = 1.75
1.75·3 = 5.25 gal. to purge

INITIAL GROUNDWATER DEPTH (FT) 17.25' BTC
SAMPLING PERIOD: START 1429 COMPLETE 1543
SAMPLING METHOD B LOGGER CODE RAON
LAB CODE RAON DATE SENT 4-25-90
PRESERVATION METHOD 4°C; HNO_3 - METALS
COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.89	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	1250	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0
TOTAL UNFILTERED ALK = 934 mg/L TOTAL FILTERED ALK = 389

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1409	0.0	0.0	-	-	-	START PUMPING
1411	1.0		6.70	1645	69.5°F	DK. BROWN VERY TURBID
1414	2.5		6.78	1629	69.5°F	"
1416	3.5		6.82	1605	69.5°F	"
1418	4.5		6.85	1520	69.5°F	"
1420	5.0		6.86	1440	69.5°F	MED. BROWN, MOD. TO VERY TUR
1423	6.0		6.86	1360	69.5°F	"
1425	7.0		6.87	1320	69.5°F	"
1427	8.0		6.88	1260	69.5°F	"
1428	9.0		6.89	1250	69.5°F	"

SAMPLES TYPES: (WSACODE)
D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)
G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD 73 324

INSTALLATION ID CSWL LOG DATE 4-25-90 LOG TIME 1230

LOCATION ID LF05-02 LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 22.70 B

T.D. = 30.1' BTC (Sounded)

INITIAL GROUNDWATER DEPTH (FT) 22.70' BTC 7.4·0.17=1.26·3=3.78 g

SAMPLING PERIOD: START 1303 COMPLETE 1319

SAMPLING METHOD B LOGGER CODE RADN

LAB CODE RADN DATE SENT 4-25-90

PRESERVATION METHOD 4°C; HNO_3-METALS

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.61	0.0
SPECIFIC CONDUCTANCE	SC	µmhos/cm	1250	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0

TOTAL UNFILTERED ALK = 480 mg/L TOTAL FILTERED ALK = 476 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1251	0.0	0.0	-	-	-	START PUMPING
1254	1.0		6.55	1250	69°F	ALMOST CLEAR, PINK TINT
1256	2.0		6.59	1260	68.5°F	"
1258	3.0		6.63	1254	68°F	"
1300	4.0		6.61	1250	67.5°F	"

SAMPLES TYPES: (WSACODE)

D - DUPLICATE; FB - FIELD BLANK; R - REPLICATE; TB - TRIP BLANK; S - SPIKE; LB - LAB BLANK; K - KNOWN; N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB; SP - SUBMERSIBLE PUMP; B - BAILER; AL - AIR-LIFT SAMPLER; PP - PERISTALIC PUMP; BP - BLADDER PUMP; SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

INSTALLATION ID OSWL LOG DATE 4/18/90 LOG TIME 0800
LOCATION ID LF05-14 LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 8.98 (BTC)

INITIAL GROUNDWATER DEPTH (FT) 8.98 BTC   12.87 - 8.98 = 3.89 x 0.17 = 0.66
0.66 x 3 = 1.98/3 [illegible]
SAMPLING PERIOD: START 0855 COMPLETE 0915
SAMPLING METHOD B LOGGER CODE KADN
LAB CODE KADN DATE SENT 4/18/90
PRESERVATION METHOD 4°C; HNO_3 - METALS
COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.63	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	960	1
REDOX POTENTIAL	Eh	mvolts		
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

Phenopthalein (P) Alkalinity = 0.0 mg/L
Total Alkalinity unfiltered 1.212 mg/L Filtered = 399 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
0840	0.0	0.0	-	-	-	START PUMPING
0845	1.0	1.50	6.54	930	61°F	Lt. orange-tan, mod. turbid
0848	2.0	3.03	6.61	960	61.5	"
0852	3.0	4.55	6.63	960	61.5	"
0853	3.5	5.30	—	—	—	End purge.

SAMPLES TYPES: (WSACODE)

D - DUPLICATE   FB - FIELD BLANK
R - REPLICATE   TB - TRIP BLANK
S - SPIKE   LB - LAB BLANK
K - KNOWN   N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB   SP - SUBMERSIBLE PUMP
B - BAILER   AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP   BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

73 326

INSTALLATION ID CSWL LOG DATE 4/17/90 LOG TIME 1450

LOCATION ID LF05-18 LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 18.21 BTC

TD = 23.7' BTC

23.7 − 18.21 = 5.49

5.49 x 0.17 = 0.93 x 3 =

INITIAL GROUNDWATER DEPTH (FT) 18.21 BTC

SAMPLING PERIOD: START 1513 COMPLETE 1600

SAMPLING METHOD B LOGGER CODE RADN

LAB CODE RADN DATE SENT 4/17/90

PRESERVATION METHOD 4°C; HNO_3 (pH<2) WITH METALS

COMMENTS

W.L. AFTER SAMPLING = 18.24' BTC

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.46	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	922	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C	18.5	0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

Phenopthalein = 0.0

Total alkalinity unfiltered = 508 mg/L filtered = 393 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (WETTED CASING) (Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
	0.0	0.0	-	-	-	START PUMPING
1458	1.0	1.07	6.48	960	18.5	tannish brn / very turbid
1502	2.0	2.14	6.56	900	18.5	" "
1506	3.0	3.21	6.44	870	18.5	" "
1511	4.0	4.29	6.46	922	18.5	" "

SAMPLES TYPES: (WSACODE)

- D - DUPLICATE
- R - REPLICATE
- S - SPIKE
- K - KNOWN
- FB - FIELD BLANK
- TB - TRIP BLANK
- LB - LAB BLANK
- N - NORMAL

SAMPLE METHODS: (WSMCODE)

- G - GRAB
- B - BAILER
- PP - PERISTALIC PUMP
- SL - SUCTION LIFT PUMP
- SP - SUBMERSIBLE PUMP
- AL - AIR-LIFT SAMPLER
- BP - BLADDER PUMP

GROUND WATER QUALITY SAMPLING RECORD

INSTALLATION ID CSWL LOG DATE 4/17/90 LOG TIME 1310
LOCATION ID LF05-19 LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 12.89 BTC

19.72-12.89=6.83 x 0.17=1.16
1.16x3=3.48

INITIAL GROUNDWATER DEPTH (FT) 12.89 BTC
SAMPLING PERIOD: START 1350 COMPLETE 1410
SAMPLING METHOD B LOGGER CODE KADN
LAB CODE KADN DATE SENT 4/17/90
PRESERVATION METHOD 4°C, HNO_3 (pH<2) WITH METALS
COMMENTS

FINAL G.W. DEPTH = 12.88 BTC

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.84	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	830	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C	18.6	0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHENOLPHTHALEIN = 0.0
TOTAL = 475 MG/L (NON-FILTERED) FILTERED = 376 MG/L

TIME	TOTAL VOLUME WITHDRAWN (WETTED CASING) (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1318	0.0	0.0	-	-	-	START PUMPING
1327	1.5	1.29	6.70	850	18.7	ORANGE/BROWN, MOD.-VERY TURB.
1331	2.5	2.15	6.84	840	18.5	ORANGE/BROWN, MOD. TURBID
1335	4.0	3.45	6.84	830	18.6	"
1340	4.5	3.88	—	—	—	"

SAMPLES TYPES: (WSACODE)
D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)
G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD 73 328

INSTALLATION ID CSWL LOG DATE 5-1-90 LOG TIME 1320

LOCATION ID LF05-5A LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 22.38 BTC

INITIAL GROUNDWATER DEPTH (FT) 22.38 BTC T.D. = 30.52' BTC (SOUNDED) 4.15gal = 3 wetted csg vol

SAMPLING PERIOD: START 1405 COMPLETE 1413

SAMPLING METHOD B LOGGER CODE RADN

LAB CODE RADN DATE SENT 5-7-90

PRESERVATION METHOD 4°C. HNO_3 - METALS

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.73	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	886	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 00

TOTAL UNFILTERED ALK = 398 TOTAL FILTERED ALK = 395

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1350	0.0	0.0	-	-	-	START PUMPING
1352	1.0		6.70	844	66.0°F	ORANGE/BROWN. MOD. TURBID
1355	2.0		6.76	899	66.0°F	ORANGE/BROWN. SLIGHTLY - MOD TURBID
1357	3.0		6.73	896	66.0°F	"
1359	4.0		6.74	893	66.0°F	SLIGHTLY TURBID
1401	5.0		6.73	886	66.1°F	ALMOST CLEAR

SAMPLES TYPES: (WSACODE)

D - DUPLICATE
R - REPLICATE
S - SPIKE
K - KNOWN
FB - FIELD BLANK
TB - TRIP BLANK
LB - LAB BLANK
N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB
B - BAILER
PP - PERISTALIC PUMP
SL - SUCTION LIFT PUMP
SP - SUBMERSIBLE PUMP
AL - AIR-LIFT SAMPLER
BP - BLADDER PUMP

GROUND WATER QUALITY SAMPLING RECORD

INSTALLATION ID CSWL LOG DATE 5-11-90 LOG TIME 1250
LOCATION ID LF05-5B LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 3.10 BTC

INITIAL GROUNDWATER DEPTH (FT) 3.10' BTC T.D. = 12.65' BTC (SOUNDED) 4.87 gal to purge
SAMPLING PERIOD: START 1317 COMPLETE 1325
SAMPLING METHOD B LOGGER CODE RAAN
LAB CODE RAAN DATE SENT 5-11-90
PRESERVATION METHOD 4°C; HNO₃ - METALS
COMMENTS WATER PONDED AROUND WELL

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.83	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	974	1
REDOX POTENTIAL	Eh	mvolts		—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

Phen Alk = 0.0
Total Alk = 504 Filtered = 502

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1307	0.0	0.0	-	-	-	START PUMPING
1309	1.0		6.79	969	65.8°F	ALMOST CLEAR
1311	2.5		6.80	967	66.0°F	"
1313	3.5		6.79	975	65.5°F	"
1315	5.0		6.83	974	65.5°F	", SLIGHTLY TURBID

SAMPLES TYPES: (WSACODE)
D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)
G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALTIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

INSTALLATION ID CSWL LOG DATE 5-1-90 LOG TIME 1500

LOCATION ID LF05-5C LOT CONTROL NO. ______

SAMPLE TYPE N SAMPLE ID ______ SAMPLE DEPTH (FT.) 9.45 BTC

INITIAL GROUNDWATER DEPTH (FT) 9.45 BTC T.D. = 20.46' BTC (SOUNDED) 5.5 gal = 3 wetted casing [illegible]

SAMPLING PERIOD: START ______ COMPLETE 1520

SAMPLING METHOD B LOGGER CODE RADN

LAB CODE RADN DATE SENT 5-1-90

PRESERVATION METHOD 4°C ; HNO_3-METALS

COMMENTS ______

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.52	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	1173	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN ALK = 0.0
TOTAL UNFILTERED ALK = 599 Filtered 597

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1456	0.0	0.0	-	-	-	START PUMPING
1459	2.0		6.48	1054	66.2°F	IT BROWN SLIGHTLY T[illegible]
1501	4.0		6.44	1150	66.5°F	"
1503	5.0		6.60	1190	66.3°F	ALMOST CLEAR, SLIGHTLY C[illegible]
1504	5.5		6.77	1180	66.2°F	"
1506	6.0		6.89	1172	66.1°F	"
1507	6.5		6.47	1171	66.1°F	pH was wandering up
1509	7.0		6.52	1173	66.1°F	ALMOST CLEAR

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALTIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD 73 331

INSTALLATION ID CSWL LOG DATE 5-11-90 LOG TIME 0920

LOCATION ID LF05-5D LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 9.75 BTC

INITIAL GROUNDWATER DEPTH (FT) 9.75 BTC T.D. = 21.25 BTC (sounded) 5.87 gal = 3 wetted casing vol.

SAMPLING PERIOD: START 0940 COMPLETE 0947

SAMPLING METHOD B LOGGER CODE RAON

LAB CODE RAON DATE SENT 5-11-90

PRESERVATION METHOD 4°C; HNO_3-METALS

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.63	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	1155	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

Phen Alk = 00

Unfiltered Total Alk = not taken Filtered = 605 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
0926	0.0	0.0	-	-	-	START PUMPING
0928	1.5		6.59	1145	65.0°F	LT. BROWN, SLIGHTLY TURBID
0933	3.0		6.68	1151	65.5°F	"
0936	4.5		6.63	1166	65.6°F	"
0939	6.0		6.63	1155	65.8°F	

SAMPLES TYPES: (WSACODE)

D - DUPLICATE
R - REPLICATE
S - SPIKE
K - KNOWN
FB - FIELD BLANK
TB - TRIP BLANK
LB - LAB BLANK
N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB
B - BAILER
PP - PERISTALTIC PUMP
SL - SUCTION LIFT PUMP
SP - SUBMERSIBLE PUMP
AL - AIR-LIFT SAMPLER
BP - BLADDER PUMP

GROUND WATER QUALITY SAMPLING RECORD 73 332

INSTALLATION ID CSWL LOG DATE 5-1-90 LOG TIME 1100
LOCATION ID LF05-5E LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 26.52 BTC

T.D. = 36.20 BTC (SOUNDED)
4.94 gal = 3 wetted casing v
INITIAL GROUNDWATER DEPTH (FT) 26.52 BTC
SAMPLING PERIOD: START 1128 COMPLETE 1135
SAMPLING METHOD B LOGGER CODE RAON
LAB CODE RAON DATE SENT 5-1-90
PRESERVATION METHOD 4°C · HNO_3-METALS
COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.77	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	802	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0.0
TOTAL UNFILTERED ALK = 1202 TOTAL FILTERED ALK = 356

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP (°C)	COMMENTS
1115	0.0	0.0	-	-	-	START PUMPING
1119	1.0		6.75	808	67.9°F	ORANGE/BROWN, VERY TURBI..
1121	2.5		6.76	800	67.7°F	"
1123	3.0		6.80	801	67.6°F	"
1125	4.0		6.79	801	67.6°F	"
1127	5.0		6.77	802	67.8°F	"

SAMPLES TYPES: (WSACODE)
D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)
G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

73 333

INSTALLATION ID CSWL LOG DATE 4-26-90 LOG TIME 1300

LOCATION ID LF05-5F LOT CONTROL NO. ______

SAMPLE TYPE N, MS, MSD & EB SAMPLE ID ______ SAMPLE DEPTH (FT.) 22.76 BTC

INITIAL GROUNDWATER DEPTH (FT) 22.76 BTC

T.D. = 36.80' BTC (SOUNDED)
14.04 · 0.17 = 2.39 · 2.39 · 3 = 7.17

SAMPLING PERIOD: START 1406 COMPLETE 1445

SAMPLING METHOD B LOGGER CODE RADN

LAB CODE RADN DATE SENT 4-26-90

PRESERVATION METHOD 4°C; HNO_3-METALS

COMMENTS ______

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.89	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	929	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0.0
TOTAL UNFILTERED ALK. 403 mg/L TOTAL FILTERED ALK. = 358 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP (°C)	COMMENTS
1345	0.0	0.0	-	-	-	START PUMPING
1348	1.0		6.85	705	68.0°F	LIGHT ORANGE/BROWN MOD. TURBID
1352	2.0		6.87	873	68.0°F	" , SLIGHTLY TURBID
1354	3.0		6.89	910	68.0°F	"
1356	4.0		6.90	921	67.5°F	"
1358	5.0		6.89	928	68.0°F	"
1400	6.0		6.88	923	68°F	"
1404	7.5		6.89	929	68°F	"
			EQUIPMENT BLANK			
1522	—		6.65	1	66°F	CLEAR
			ALKALINITY = 0.0			

SAMPLES TYPES: (WSACODE)
D - DUPLICATE
R - REPLICATE
S - SPIKE
K - KNOWN
FB - FIELD BLANK
TB - TRIP BLANK
LB - LAB BLANK
N - NORMAL

SAMPLE METHODS: (WSMCODE)
G - GRAB
B - BAILER
PP - PERISTALTIC PUMP
SL - SUCTION LIFT PUMP
SP - SUBMERSIBLE PUMP
AL - AIR-LIFT SAMPLER
BP - BLADDER PUMP

GROUND WATER QUALITY SAMPLING RECORD

73 334

INSTALLATION ID CSWL LOG DATE 4/18/90 LOG TIME 0950

LOCATION ID SG LF05-5G LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 20.15 (BT

INITIAL GROUNDWATER DEPTH (FT) 20.15 (TOC)

T.D. = 30.3 30.3 − 20.15 = 10.15
10.15 x 0.17 = 1.73 gl water
5.19 g/3 well vols

SAMPLING PERIOD: START 1022 COMPLETE 1045

SAMPLING METHOD B LOGGER CODE RADN

LAB CODE RADN DATE SENT 4/18/90

PRESERVATION METHOD 4°C; HNO_3 (pH<2) with metals

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.67	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	990	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHENOLPHTHALEIN ALKALINITY = 0
UNFILTERED TOTAL ALK. = 455 mg/L TOTAL ALK. FILTERED = 405 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes) well casing	pH	SC (µmhos/cm)	TEMP (°C)	COMMENTS
0954	0.0	0.0	-	-	-	START PUMPING
1002	1.0	0.58	6.43	960	63°F	WATER SLIGHTLY TURBID
1005	2.5	1.45	6.50	980	65°F	"
1009	4.0	2.31	6.63	990	65°F	LIGHT TAN SLIGHTLY TURBID
1015	5.0	2.89	6.67	990	64.5 F	"
1018	6.0	3.47	—	—	—	"

SAMPLES TYPES: (WSACODE)

- D - DUPLICATE
- R - REPLICATE
- S - SPIKE
- K - KNOWN
- FB - FIELD BLANK
- TB - TRIP BLANK
- LB - LAB BLANK
- N - NORMAL

SAMPLE METHODS: (WSMCODE)

- G - GRAB
- B - BAILER
- PP - PERISTALTIC PUMP
- SL - SUCTION LIFT PUMP
- SP - SUBMERSIBLE PUMP
- AL - AIR-LIFT SAMPLER
- BP - BLADDER PUMP

GROUND WATER QUALITY SAMPLING RECORD

INSTALLATION ID CSWL LOG DATE 4/18/90 LOG TIME 1550
LOCATION ID LF05-5H LOT CONTROL NO. ______
SAMPLE TYPE N SAMPLE ID ______ SAMPLE DEPTH (FT.) 14.92 (BTC

INITIAL GROUNDWATER DEPTH (FT) 14.92 (BTC) 27.96' TD → 13.04 x 0.17 = 2.2 g
3 WETTED CASINGS = 6.65 g
SAMPLING PERIOD: START 1620 COMPLETE 1647
SAMPLING METHOD B LOGGER CODE KADN
LAB CODE KADN DATE SENT 4/18/90
PRESERVATION METHOD 4°C ; HNO3 IN METALS (PH < 2)
COMMENTS ______

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.40	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	1000	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

Phenolphthalein Alk = 0
Unfiltered Total = 395 mg/L Filtered = 392 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	Wetted Casing ~~(Bore Volumes)~~	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
1555	0.0	0.0	-	-	-	START PUMPING
1600	2.0	0.91	6.20	1010	63.5 F°	Light gray, slightly cloudy
1606	2.5	1.14	6.20	1010	63.5°F	"
1609	4.0	1.82	5.60	1010	64°F	Almost clear
1611	5.0	2.27	6.30	990	63.5°F	"
1614	6.0	2.73	6.45	1010	63.5°F	"
1616	7.0	3.18	6.40	1000	63.5°F	"
1618	7.5	3.41	—	—	—	End purge

SAMPLES TYPES: (WSACODE)
D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)
G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

73 336

INSTALLATION ID CSWL LOG DATE 5-11-90 LOG TIME 1045

LOCATION ID FT08-11A LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 8.98 BTC

INITIAL GROUNDWATER DEPTH (FT) 8.98 BTC T.D. = 17.68' BTC (SOUNDED) 4.44 gal to purge

SAMPLING PERIOD: START 1102 COMPLETE 1118

SAMPLING METHOD B LOGGER CODE RAON

LAB CODE RAON DATE SENT 5-11-90

PRESERVATION METHOD 4°C; HNO_3-METALS

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	7.05	0.0
SPECIFIC CONDUCTANCE	SC	µmhos/cm	779	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.
ALKALINITY ($CaCO_3$)	ALK	mg/l		

Phenol Alk 0.0

Unfiltered Total Alk = Not taken Filtered = 353 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP (°C)	COMMENTS
1048	0.0	0.0	-	-	-	START PUMPING
1051	1.0		7.07	723	65.5°F	LT. BROWN, SLIGHTLY TURBID
1054	2.5		7.04	762	65.5°F	"
1057	3.5		7.07	756	65.5°F	" , SLIGHTLY TO MOD. TURBID
1059	5.0		7.05	785	65.3°F	"
1101	5.5		7.05	779	65.5°F	"

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

73 337

GROUND WATER QUALITY SAMPLING RECORD

INSTALLATION ID CSWL LOG DATE 5-11-90 LOG TIME 1000

LOCATION ID FWB-11B LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 7.34 BTC

INITIAL GROUNDWATER DEPTH (FT) 7.34 BTC T.D = 17.18 BTC (SOUNDED) 3.02 gal to purge

SAMPLING PERIOD: START 1023 COMPLETE 1027

SAMPLING METHOD B LOGGER CODE RAON

LAB CODE RAON DATE SENT 5-11-90

PRESERVATION METHOD 4°C; HNO_3-METALS

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.78	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	1237	1
REDOX POTENTIAL	Eh	mvolts		
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

Phen Alk = 0.0

UNFILTERED ALK = NOT TAKEN FILTERED ALK = 562 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP (°C)	COMMENTS
1012	0.0	0.0	-	-	-	START PUMPING
1014	1.0		6.75	1144	65.8°F	LT. BROWN, SLIGHTLY TURBI
1017	2.5		6.80	1187	65.6°F	"
1019	4.0		6.78	1239	65.3°F	"
1021	5.5		6.78	1237	65.2°F	"

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALTIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

INSTALLATION ID CSWL LOG DATE 4-30-90 LOG TIME 0915
LOCATION ID FT09-12A LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 15.17' BTC

INITIAL GROUNDWATER DEPTH (FT) 15.17' BTC T.D. = 27.4' BTC (SURVEY) 6.49 gal = 3 wetted casing volumes
SAMPLING PERIOD: START 1035 COMPLETE 1043
SAMPLING METHOD B LOGGER CODE RADN
LAB CODE RADN DATE SENT 4-30-90
PRESERVATION METHOD 4°C; HNO_3 - METALS; HCL - PET. H.C.
COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	7.10	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	579	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK. 0.0
TOTAL UNFILTERED ALK = 293 TOTAL FILTERED ALK = 286

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP (°C)	COMMENTS
1005	0.0	0.0	-	-	-	START PUMPING
1013	1.0		7.00	638	70.0°F	WATER CLEAR
1020	2.0		7.12	581	65.5°F	SLIGHTLY CLOUDY
1024	3.5		7.09	580	65.5°F	"
1026	5.5		7.09	578	65.5°F	"
1029	7.0		7.10	579	65.5°F	"

SAMPLES TYPES: (WSACODE)
D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)
G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALTIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

73 339

INSTALLATION ID CSWL LOG DATE 4-30-90 LOG TIME 1105

LOCATION ID FT09-12B LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 29.15 BTC

T.D. = ~~29.15~~ 37.75 BTC (SOUNDED)
4.39 gal = 3 wetted casing vo.

INITIAL GROUNDWATER DEPTH (FT) 29.15 BTC

SAMPLING PERIOD: START 1135 COMPLETE 1145

SAMPLING METHOD B LOGGER CODE

LAB CODE RAON DATE SENT

PRESERVATION METHOD 4°C. HNO_3 - METALS; HCL - PETROLEUM HYDROCARBONS

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.77	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	822	1
REDOX POTENTIAL	Eh	mvolts		
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK. = 0.0
TOTAL UNFILTERED ALK = 412 TOTAL FILTERED ALK = 395

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP (°C)	COMMENTS
1119	0.0	0.0	-	-	-	START PUMPING
1121	0.5		6.67	833	69.5°F	CLEAR
1125	1.5		6.69	829	69.5°F	"
1127	2.5		6.70	827	69.0°F	"
1129	3.0		6.73	827	69.5°F	"
1132	4.0		6.72	824	69.5°F	"
1133	4.5		6.77	822	69.0°F	"

SAMPLES TYPES: (WSACODE)

- D - DUPLICATE
- R - REPLICATE
- S - SPIKE
- K - KNOWN
- FB - FIELD BLANK
- TB - TRIP BLANK
- LB - LAB BLANK
- N - NORMAL

SAMPLE METHODS: (WSMCODE)

- G - GRAB
- B - BAILER
- PP - PERISTALTIC PUMP
- SL - SUCTION LIFT PUMP
- SP - SUBMERSIBLE PUMP
- AL - AIR-LIFT SAMPLER
- BP - BLADDER PUMP

GROUND WATER QUALITY SAMPLING RECORD 73 34

INSTALLATION ID USVL LOG DATE 4-30-90 LOG TIME 1300

LOCATION ID & FT09-12C LOT CONTROL NO.

SAMPLE TYPE N & EB SAMPLE ID SAMPLE DEPTH (FT.) 30.04

INITIAL GROUNDWATER DEPTH (FT) 30.04 BTC TD = 40.00 BTC (SOUNDED); 5.08 gal = 3 vol

SAMPLING PERIOD: START 1354 COMPLETE 1419

SAMPLING METHOD B LOGGER CODE RADN

LAB CODE RADN DATE SENT 4-30-90

PRESERVATION METHOD 4°C; HNO₃-METALS; HCL-PET. HC

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.52	0.0
SPECIFIC CONDUCTANCE	SC	µmhos/cm	850	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0.0

TOTAL UNFILTERED ALK = 622 TOTAL FILTERED ALK = 458

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP (°C)	COMMENTS
1326	0.0	0.0	-	-	-	START PUMPING
1331	1.0		6.56	913	69.0°F	LT BROWN/GRAY, SLIGHTLY TURB
1336	2.5		6.59	878	68.2°F	"
1342	3.0		6.51	880	69.0	"
1345	4.0		6.51	868	68.5	"
1350	5.0		6.52	847	68.7	"
1352	6.0		6.49	860	69.0	"
1354	6.5		6.52	850	68.8	"
	EQUIPMENT			BLANK		
			7.63	004	69.5°F	CLEAR
			UNF	ALK = 0.0		
			FILTERED	ALK	= 0.0	

SAMPLES TYPES: (WSACODE)

- D - DUPLICATE
- R - REPLICATE
- S - SPIKE
- K - KNOWN
- FB - FIELD BLANK
- TB - TRIP BLANK
- LB - LAB BLANK
- N - NORMAL

SAMPLE METHODS: (WSMCODE)

- G - GRAB
- B - BAILER
- PP - PERISTALIC PUMP
- SL - SUCTION LIFT PUMP
- SP - SUBMERSIBLE PUMP
- AL - AIR-LIFT SAMPLER
- BP - BLADDER PUMP

GROUND WATER QUALITY SAMPLING RECORD

INSTALLATION ID CSWL LOG DATE 4-30-90 LOG TIME 1510
LOCATION ID FT09-12D LOT CONTROL NO.
SAMPLE TYPE N & D SAMPLE ID SAMPLE DEPTH (FT.) 28.65 BTC

INITIAL GROUNDWATER DEPTH (FT) 28.65 BTC T.D. = 37.02' BTC (SOUNDED) 4.27 gal = 3 wetted csg. vol.
SAMPLING PERIOD: START 1537 COMPLETE 1602
SAMPLING METHOD B LOGGER CODE RADN
LAB CODE RADN DATE SENT
PRESERVATION METHOD 4°C; ANAL - METALS · HCL - PET. H.C.
COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.76	0.01
SPECIFIC CONDUCTANCE	SC	μmhos/cm	813	1
REDOX POTENTIAL	Eh	mvolts	—	
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK. 0.0
TOTAL UNFILTERED ALK. = 599 TOTAL FILTERED ALK. = 345 mg/L

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (μmhos/cm)	TEMP (°C)	COMMENTS
1520	0.0	0.0	-	-	-	START PUMPING
1524	1.0		6.81	801	68.2°F	ORANGE/BROWN MOD. TURBID
1527	2.0		7.04	812	67.8°F	"
1529	3.0		6.79	807	68.2°F	"
1531	4.0		6.78	816	68.2°F	"
1533	4.5		6.76	813	68.2°F	"

SAMPLES TYPES: (WSACODE)
D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)
G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

GROUND WATER QUALITY SAMPLING RECORD

73 343

INSTALLATION ID CSWL LOG DATE 5-11-90 LOG TIME 0800

LOCATION ID WP07-10A LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 25.91 BTC

INITIAL GROUNDWATER DEPTH (FT) 85.91 BTC T.D. = 37.92 BTC (SOUNDED) 2.13 gal to purge

SAMPLING PERIOD: START 0858 COMPLETE 0904

SAMPLING METHOD B LOGGER CODE RAON

LAB CODE RAON DATE SENT 5-11-90

PRESERVATION METHOD 4°C; HNO_3-METALS

COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.80	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	834	1
REDOX POTENTIAL	Eh	mvolts		—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

Phenol Alk = 0.0

Unfiltered Total Alk - not taken Filtered = 394

TIME	TOTAL VOLUME WITHDRAWN (GALS)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
0835	0.0	0.0	–	–	–	START PUMPING
0839	1.0		6.86	792	68.0°F	LT. TAN, SLIGHTLY TURBID
0845	2.5		6.79	833	68.0°F	"
0848	4.0		6.87	835	67.8°F	"
0853	5.0		6.84	840	67.8°F	"
0857	6.5		6.80	834	68.0°F	"

SAMPLES TYPES: (WSACODE)

D - DUPLICATE
R - REPLICATE
S - SPIKE
K - KNOWN
FB - FIELD BLANK
TB - TRIP BLANK
LB - LAB BLANK
N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB
B - BAILER
PP - PERISTALIC PUMP
SL - SUCTION LIFT PUMP
SP - SUBMERSIBLE PUMP
AL - AIR-LIFT SAMPLER
BP - BLADDER PUMP

GROUND WATER QUALITY SAMPLING RECORD

73 344

PAGE 1 OF 1

INSTALLATION ID CSWL LOG DATE 5-11-90 LOG TIME 1500

LOCATION ID WP07-10B LOT CONTROL NO.

SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) ~25.5 BT

Phen Alk 300
total Alk 390 filtered - 390

W.L. ~25.5 BTC (used tape, E-line not working properly)

T.D = 34.55' BTC

TIME	TOTAL VOLUME WITHDRAWN (GALS)	(Bore Volumes)	pH	SC (µmhos/cm)	TEMP. (°C)	4.62 gal to purge COMMENTS
1512			—			START BAILING
1516	1.0		6.86	799	69.8°F	ALMOST CLEAR
1519	2.0		6.87	797	69.8°F	LT. BROWN. SLIGHTLY TURB.
1523	3.0		6.85	793	69.8°F	"
1529	5.0		6.84	796	69.5°F	"
1532	- START SAMPLING					
1537	- END SAMPLING					

GROUND WATER QUALITY SAMPLING RECORD 73 345

INSTALLATION ID CSWL LOG DATE 5-11-90 LOG TIME 1345
LOCATION ID WP07-10C LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 18.30 BTC

INITIAL GROUNDWATER DEPTH (FT) 18.30 BTC T.D. = 29.00' BTC (SOUNDED) 5.46 gal = purge 3 wetted casings
SAMPLING PERIOD: START 1403 COMPLETE 1410
SAMPLING METHOD B LOGGER CODE RAON
LAB CODE RAON DATE SENT 5-11-90
PRESERVATION METHOD 4°C; HNO_3 - METALS
COMMENTS

FINAL PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.68	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	939	1
REDOX POTENTIAL	Eh	mvolts		—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0
TOTAL UNFILTERED = 477 mg/L Filtered 446

TIME	TOTAL VOLUME WITHDRAWN		pH	SC (µmhos/cm)	TEMP. (°C)	COMMENTS
	(GALS)	(Bore Volumes)				
1348	0.0	0.0	-	-	-	START PUMPING
1351	1.0	1.0	6.70	953	69.0°F	ALMOST CLEAR
1354	2.5		6.71	951	69.5°F	" , SLIGHTLY CLOUDY
1357	3.5		6.73	949	69.8°F	"
1400	5.0		6.68	939	69.8°F	"
1402	5.5		—	—	—	END PURGE

SAMPLES TYPES: (WSACODE)

D - DUPLICATE FB - FIELD BLANK
R - REPLICATE TB - TRIP BLANK
S - SPIKE LB - LAB BLANK
K - KNOWN N - NORMAL

SAMPLE METHODS: (WSMCODE)

G - GRAB SP - SUBMERSIBLE PUMP
B - BAILER AL - AIR-LIFT SAMPLER
PP - PERISTALTIC PUMP BP - BLADDER PUMP
SL - SUCTION LIFT PUMP

SURFACE WATER QUALITY SAMPLING RECORD

73 346

INSTALLATION ID CSWL LOG DATE 5-8-90 LOG TIME 0830
LOCATION ID LF05-S1 LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 0.5' BWS

SAMPLING PERIOD: START 0910 COMPLETE 0936
SAMPLING METHOD G LOGGER CODE RAON
LAB CODE RAON DATE SENT 5-8-90
PRESERVATION METHOD 4°C; HNO_3-METALS
COMMENTS WATER CLOUDY, GRAY/GREEN

PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	8.00	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	644	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

Phenolphthalein Alkalinity 0.0
Total Alkalinity = 295 mg/L Filtered = 210 mg/L TEMP = 68.2° F

INSTALLATION ID CSWL LOG DATE 5-8-90 LOG TIME 0958
LOCATION ID LF05-S7 LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 0.5 BWS

SAMPLING PERIOD: START 1006 COMPLETE 1035
SAMPLING METHOD G LOGGER CODE RAON
LAB CODE RAON DATE SENT 5-8-90
PRESERVATION METHOD 4°C; HNO_3-METALS
COMMENTS WATER CLEAR

PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.96	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	824	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK. = 0 TEMP = 66.2°F
TOTAL UNFILTERED = 330 mg/L TOTAL FILTERED ALK = 340 mg/L

SAMPLE TYPES: (WSACODE)

- D - DUPLICATE
- R - REPLICATE
- S - SPIKE
- K - KNOWN
- FB - FIELD BLANK
- TB - TRIP BLANK
- LB - LAB BLANK
- N - NORMAL

SAMPLE METHODS: (WSMCODE)

- G - GRAB
- B - BAILER
- PP - PERISTALIC PUMP
- SL - SUCTION LIFT PUMP
- SP - SUBMERSIBLE PUMP
- AL - AIR-LIFT SAMPLER
- BP - BLADDER PUMP

SURFACE WATER QUALITY SAMPLING RECORD

73 347

INSTALLATION ID CSWL LOG DATE 5-8-90 LOG TIME 1300
LOCATION ID LF05-54 LOT CONTROL NO.
SAMPLE TYPE R N SAMPLE ID SAMPLE DEPTH (FT.) 0.5 BWS

SAMPLING PERIOD: START 1305 COMPLETE 1315
SAMPLING METHOD G LOGGER CODE RADN
LAB CODE RADN DATE SENT 5-8-90
PRESERVATION METHOD 4°C; HNO_3 - METALS
COMMENTS POND WATER

PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	7.72	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	293	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0.0
TOTAL UNFILTERED ALK = 131 mg/L FILTERED ALK = 112 mg/L TEMP = ~~70.0~~°F (35F) 75.0°

INSTALLATION ID CSWL LOG DATE 5-8-90 LOG TIME 1330
LOCATION ID LF05-53 LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 0.5 BWS

SAMPLING PERIOD: START 1340 COMPLETE 1352
SAMPLING METHOD G LOGGER CODE RADN
LAB CODE RADN DATE SENT 5-8-90
PRESERVATION METHOD 4°C; HNO_3 - METALS
COMMENTS SMALL POND - BOTTOM SEDIMENT IS VERY SOFT BLACK MUD

PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	7.53	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	1075	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0.0
TOTAL UNFILTERED ALK = 439 mg/L TEMP = 81.2°F
TOTAL FILTERED = 435 mg/L

SAMPLE TYPES: (WSACODE)				SAMPLE METHODS: (WSMCODE)			
D -	DUPLICATE	FB -	FIELD BLANK	G -	GRAB	SP -	SUBMERSIBLE PUMP
R -	REPLICATE	TB -	TRIP BLANK	B -	BAILER	AL -	AIR-LIFT SAMPLER
S -	SPIKE	LB -	LAB BLANK	PP -	PERISTALIC PUMP	BP -	BLADDER PUMP
K -	KNOWN	N -	NORMAL	SL -	SUCTION LIFT PUMP		

SURFACE WATER QUALITY SAMPLING RECORD 73 348

INSTALLATION ID CSWL LOG DATE 5-8-90 LOG TIME 1055
LOCATION ID LF05-56 LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 0.5 BWS

SAMPLING PERIOD: START 1100 COMPLETE 1115
SAMPLING METHOD G LOGGER CODE RAON
LAB CODE RAON DATE SENT 5-8-90
PRESERVATION METHOD 4°C; HNO_3 - METALS
COMMENTS WATER SLIGHTLY CLOUDY, GREENISH TINT

PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	8.03	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	648	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN = 0.0
UNFILTERED = 231 mg/L FILTERED ALK = 220 mg/L TEMP = 69.1°F

INSTALLATION ID CSWL LOG DATE 5-8-90 LOG TIME 1215
LOCATION ID LF05-55 LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.)

SAMPLING PERIOD: START 1230 COMPLETE 1245
SAMPLING METHOD G LOGGER CODE RAON
LAB CODE RAON DATE SENT 5-8-90
PRESERVATION METHOD 4°C; HNO_3 - METALS
COMMENTS WATER SLIGHTLY CLOUDY

PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	7.99	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	629	1
REDOX POTENTIAL	Eh	mvolts		—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0.0 TEMP = 72.5°F
UNFILTERED ALK = 222 mg/L FILTERED ALK = 209 mg/L

SAMPLE TYPES: (WSACODE)				SAMPLE METHODS: (WSMCODE)			
D -	DUPLICATE	FB -	FIELD BLANK	G -	GRAB	SP -	SUBMERSIBLE PUMP
R -	REPLICATE	TB -	TRIP BLANK	B -	BAILER	AL -	AIR-LIFT SAMPLER
S -	SPIKE	LB -	LAB BLANK	PP -	PERISTALIC PUMP	BP -	BLADDER PUMP
K -	KNOWN	N -	NORMAL	SL -	SUCTION LIFT PUMP		

SURFACE WATER QUALITY SAMPLING RECORD

73 349

INSTALLATION ID CSWL LOG DATE 5-8-90 LOG TIME 1415
LOCATION ID LF05-S2 LOT CONTROL NO.
SAMPLE TYPE N & D SAMPLE ID SAMPLE DEPTH (FT.) 0.5 BWS

SAMPLING PERIOD: START 1428 COMPLETE 1445
SAMPLING METHOD G LOGGER CODE RAON
LAB CODE RAON DATE SENT 5-8-90
PRESERVATION METHOD 4°C; HNO_3-METALS
COMMENTS WATER CLOUDY, WAS INFORMED CONSTRUCTION WAS TAKING PLACE UPSTREAM

DUP. = 8.11 pH
DUP. = 612 SC

PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	8.10	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	618	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

PHEN. ALK = 0.0/0.0
TEMP = 76.2°F
TOTAL UNFILTERED = 213/210 TOTAL FILTERED ALK = 205/203

INSTALLATION ID CSWL LOG DATE 5-9-90 LOG TIME 0750
LOCATION ID SD13-S1 LOT CONTROL NO.
SAMPLE TYPE N SAMPLE ID SAMPLE DEPTH (FT.) 0.5 BWS

SAMPLING PERIOD: START 0832 COMPLETE 0849
SAMPLING METHOD G LOGGER CODE RAON
LAB CODE RAON DATE SENT 5-9-90
PRESERVATION METHOD 4°C; HCL-602 & P.H; HNO_3-METALS
COMMENTS Water has a rusty film

PARAMETER MEASUREMENTS:

				DETECTION LIMIT
POTENTIAL OF HYDROGEN	pH	S.U.	6.89	0.01
SPECIFIC CONDUCTANCE	SC	µmhos/cm	758	1
REDOX POTENTIAL	Eh	mvolts	—	—
TEMPERATURE	TEMP	°C		0.1
ALKALINITY ($CaCO_3$)	ALK	mg/l		

phenolpthaline alk = 0.0
Total Alk = 397 Filtered = 377 Temp = 69.0°F

SAMPLE TYPES: (WSACODE)

D -	DUPLICATE	FB -	FIELD BLANK
R -	REPLICATE	TB -	TRIP BLANK
S -	SPIKE	LB -	LAB BLANK
K -	KNOWN	N -	NORMAL

SAMPLE METHODS: (WSMCODE)

G -	GRAB	SP -	SUBMERSIBLE PUMP
B -	BAILER	AL -	AIR-LIFT SAMPLER
PP -	PERISTALIC PUMP	BP -	BLADDER PUMP
SL -	SUCTION LIFT PUMP		

73 353

HYDROGEOLOGIC INVESTIGATION
CARSWELL AIR FORCE BASE
FORT WORTH, TEXAS

Texas State Plane Coordinate and Elevation
of
Test Wells
Soil Gas Probes and
Sampling Points

April 8, 1988

BRITTAIN & CRAWFORD
LAND SURVEYING &
TOPOGRAPHIC MAPPING
(817) 926-0211 - Metro 429-5112
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Fort Worth, Texas 76110

BOREHOLE AND MONITOR WELL SURVEY DATA

(Monitor wells are distinguished from boreholes by having a corresponding elevation of top of P.V.C. value)

73 354

NUMBER		NORTH "Y"	EAST "X"	ELEVATION OF TOP OF P.V.C.	ELEVATION OF NATURAL GROUND AT WELL
BSS	A(45)	402,068.84192	2,024,357.78905	566.38	566.9
BSS	B(34)	402,390.17981	2,024,331.93158	569.73	567.1
BSS	C(36)	402,254.07567	2,024,565.70484	559.57	560.0
BSS	D(38)	402,418.08908	2,024,487.37097	561.45	
P1	(111)	397,712.30601	2,019,695.14307	*628.58	625.5
P2	(96)	397,542.85438	2,020,627.90845	*618.78	615.5
1A	(131)	401,089.90010	2,025,128.18992	570.27	566.5
1B	(132)	401,268.84868	2,025,291.18966	560.25	560.49 (ASP)
1C	(134)	401,032.46237	2,025,482.01757	560.00	560.31 (ASP)
1D	(137)	400,852.84768	2,025,642.78693	563.93	560.5
1E	(135)	401,173.20809	2,025,407.53205	562.25	559.4
1F	(136)	401,002.55061	2,025,607.46316	562.26	559.5
3A	(121)	398,360.53325	2,017,786.72397		633.47
3B	(118)	398,345.88397	2,018,291.94176		633.84
3C	(117)	397,831.27206	2,018,292.28878		635.39
3D	(120)	398,698.98292	2,017,477.40425	625.25	621.6
3E	(119)	398,358.43081	2,019,005.28691		622.87
4A	(129)	396,920.99434	2,020,042.19064	625.76	624.6
4B	(130)	396,940.34767	2,020,463.63663	619.90	618.4
4C	(98)	397,217.02642	2,020,785.31555	613.04	610.9
4D	(97)	397,446.17694	2,020,610.98175	615.35	613.1
4E	(95)	397,651.12948	2,020,607.56231	618.54	617.5
4F	(93)	397,680.42416	2,020,255.75892	625.36	622.8
4G	(100)	397,836.73039	2,020,857.61303	620.02	619.1
4H	(99)	397,541.43725	2,020,916.84913	613.43	610.5
5A	(109)	398,061.75689	2,019,781.72497	623.18	619.4
5B	(90)	398,520.35788	2,020,283.72459	600.45	597.4
5C	(104)	398,339.27594	2,020,196.97152	608.68	606.8
5D	(103)	398,362.32313	2,019,960.19729	611.71	608.5
5E	(110)	397,802.46440	2,019,748.19597	626.89	623.9
5F	(94)	397,904.64236	2,020,535.56245	618.95	619.4
5G	(88)	398,174.57747	2,020,894.69337	615.39	612.0
5H	(89)	398,351.69445	2,020,546.91832	610.62	608.4
10A	(108)	397,913.30549	2,020,009.97063	626.70	624.2
10B	(92)	397,899.01251	2,020,243.06886	624.46	621.1
10C	(91)	398,197.02603	2,020,267.33493	617.24	615.4
10D	(107)	397,857.53638	2,020,078.59020		623.33
10E	(106)	397,896.37914	2,020,147.65721		622.52
10F	(105)	397,946.08160	2,020,196.19956		621.47
11A	(101)	398,941.02097	2,020,086.99390	608.22	604.8
11B	(102)	398,653.41765	2,020,136.88570	608.14	603.8
12A	(124)	397,175.89292	2,019,636.22169	635.66	632.0
12B	(113)	397,333.41742	2,019,895.65480	627.55	625.6
12C	(115)	397,213.82758	2,019,968.84527	628.05	625.5
12D	(112)	397,511.40056	2,019,943.01512	627.45	624.8
12E	(114)	397,324.25035	2,020,019.35440	627.48	624.5
12G	(127)	397,111.16499	2,019,819.73011		629.22
12H	(126)	397,175.34773	2,019,813.89486		629.06
12I	(125)	397,231.20475	2,019,814.97473		269.15
12J	(128)	397,175.26975	2,019,858.53625		628.66
12K	(116)	397,222.63773	2,019,904.66442		626.74

(Monitor wells are distinguished from boreholes by having a corresponding elevation of top of P.V.C. value)

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NUMBER		NORTH "X"	EAST "Y"	ELEVATION OF TOP P.V.C. PIPE	ELEVATION OF NATURAL GROUND AT WELL
15A	(149)	400,123.22038	2,025,232.61342	570.24	570.7
15B	(148)	399,906.57343	2,025,252.78758	567.12	564.2
15C	(144)	399,884.41824	2,025,168.58849	566.89	564.3
17I	(75)	400,225.13342	2,023,849.67063	578.19	575.2
17J	(56)	400,362.97881	2,023,809.58530	579.79	577.0
17K	(72)	400,193.17235	2,024,001.90555	575.34	573.8
17L	(61)	400,394.21647	2,023,966.04349	577.27	574.4
17M	(65)	400,380.91204	2,024,264.07312	574.28	572.6

*NOTE: WELLS P1 & P2 - THE ELEVATIONS SHOWN ARE THE TOP OF THE OPERATOR NUT.

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HYDROGEOLOGIC INVESTIGATION
CARSWELL AIR FORCE BASE
FORT WORTH, TEXAS

Texas State Plane Coordinate and Elevation
of
Test Wells,
Soil Gas Probes and
Sampling Points

July 10, 1990

BRITTAIN & CRAWFORD
LAND SURVEYING &
TOPOGRAPHIC MAPPING
(817) 926-0211 - Metro 429-5112
P.O. Box 11374 * 3908 South Freeway
Fort Worth, Texas 76110

SITE LF05

NUMBER	TYPE	NORTH "Y"	EAST "X"	ELEVATION TOP OF PVC	ELEVATION NATURAL GROUND AT WELL/BORE
LF05-01	WELL	399,361.2414	2,018,791.3828	621.96	619.3
LF05-02	WELL	399,280.6409	2,019,492.0018	622.69	620.0
LF05-03	BORE	399,182.0957	2,019,488.6372		620.6
LF05-04	BORE	399,313.9245	2,019,719.9840		617.3
LF05-05	BORE	399,388.4921	2,019,785.8488		616.1
LF05-06	BORE	399,156.8559	2,020,129.6754		598.3
LF05-07	BORE	399,192.7306	2,020,230.2232		598.0
LF05-08	BORE	399,030.3142	2,020,350.8946		606.8
LF05-09	BORE	398,918.3183	2,020,361.5966		604.9
LF05-10	BORE	398,656.8688	2,019,456.1935		623.9
LF05-11	BORE	398,619.9398	2,020,446.5081		597.6
LF05-12	BORE	398,699.0930	2,020,606.7127		594.4
LF05-13	BORE	398,406.7661	2,020,738.5442		605.0
LF05-14	WELL	398,467.5329	2,020,910.0778	602.98	603.2
LF05-15	BORE	398,082.8055	2,019,457.4908		626.5
LF05-16	BORE	398,229.3914	2,021,041.6970		612.3
LF05-17	BORE	398,317.2267	2,021,241.4299		606.5
LF05-18	WELL	398,169.3001	2,021,280.2972	611.84	612.1
LF05-19	WELL	397,850.5705	2,021,663.8519	606.08	606.3

SURFACE WATER SAMPLES

NUMBER	NORTH "Y"	EAST "X"	ELEVATION OF WATER
LF05-S1	399,327.1085	2,020,155.2125	590.25
LF05-S2	399,092.2352	2,021,029.0375	584.73
LF05-S3	398,638.2009	2,020,666.7173	591.07
LF05-S4	398,564.4359	2,020,956.6955	591.21
LF05-S5	398,383.9429	2,021,422.4749	578.89
LF05-S6	398,458.7264	2,021,661.6152	576.63
LF05-S7	397,873.1003	2,021,549.6706	589.7
STAFF GAUGE	398,445.2564	2,021,286.7444	
ELEVATION OF FLOWLINE OF CREEK AT GUAGE			578.2
WATER ELEVATION AT GUAGE			579.07
ELEVATION OF 1' MARK ON GUAGE			579.44

SITE LF04

NUMBER	TYPE	NORTH "Y"	EAST "X"	ELEVATION TOP OF PVC	ELEVATION NATURAL GROUND AT WELL/BORE
LF04-01	WELL	397,653.5721	2,019,579.1905	629.24	626.5
LF04-02	WELL	397,732.5422	2,020,510.5024	623.68	621.0
LF04-03	PUMP TEST WELL	397,683.4611	2,020,506.7895	623.25	620.5
LF04-04	WELL	397,554.5294	2,021,365.8226	612.07	609.4
LF04-05	BORE	397,347.9116	2,020,805.4209		608.8
LF04-06	BORE	397,210.6006	2,020,593.2486		613.3
LF04-07	BORE	396,819.7427	2,020,897.2163		630.4
LF04-08	BORE	396,935.0825	2,021,021.9109		630.0
LF04-09	BORE	397,136.0543	2,021,145.6966		627.4
LF04-10	WELL	397,025.3443	2,021,275.0320	626.54	626.9

SITE ST14

NUMBER	TYPE	NORTH "Y"	EAST "X"	ELEVATION TOP OF PVC	ELEVATION NATURAL GROUND AT WELL/BORE
ST14-01	WELL	399,886.0854	2,024,309.3181	575.89	573.2
ST14-02	WELL	400,102.4353	2,024,311.8094	575.64	572.7
ST14-03	WELL	400,672.3650	2,024,116.0939	576.72	574.83 ASP
ST14-04	WELL	400,231.5326	2,024,566.4807	575.74	572.9

SITE SD13

NUMBER	TYPE	NORTH "Y"	EAST "X"	ELEVATION TOP OF PVC	ELEVATION NATURAL GROUND AT WELL/BORE
SD13-01	WELL	399,964.3693	2,024,842.2218	573.24	570.3
SD13-02	WELL	400,058.5313	2,024,974.4094	573.39	570.64 ASP
SD13-03	WELL	399,934.0917	2,024,919.8140	571.54	568.6
SD13-04	WELL	399,931.9664	2,024,992.0174	569.24	566.81 ASP

SURFACE WATER SAMPLES

NUMBER	NORTH "Y"	EAST "X"	WATER ELEVATION
SD13-S1	399,722.7878	2,025,153.1150	551.64
SD13-S2	399,729.5605	2,025,176.1395	551.14
SD13-S3	399,747.0566	2,025,235.6200	549.72
SD13-S4	399,757.2157	2,025,270.1565	548.95

1.0 INTRODUCTION

The IRP Phase I and Phase II investigations have identified the Flightline Area at Carswell AFB as an on-base site where past waste disposal practices may have led to contamination of soils and ground water. These studies have identified a need to understand the hydrogeologic framework controlling the occurrence of ground water and the factors influencing the direction and rate of ground-water flow. Therefore, an aquifer pumping and recovery test was conducted at the Flightline Area during June, 1990 as part of an on-going IRP Remedial Investigation/Feasibility Study (RI/FS). The objective of the aquifer tests was to determine the hydraulic characteristics of the shallow ground-water bearing zone (Upper Zone Aquifer). The following sections describe the geologic setting of the Flightline Area, aquifer test procedures, and test results.

1.1 Principles of Aquifer Pumping Tests

The value of an aquifer as a source of ground water depends upon water quality and the capacity of the aquifer to store and transmit water. The latter two characteristics are referred to as the properties of storage and transmissivity. The transmissivity is a function of an aquifer's hydraulic conductivity. The hydraulic conductivity is defined as the flow of water in cubic feet per day through a cross-sectional area of one square foot under a hydraulic gradient of one foot per foot (Davis and DeWeist, 1966). Hydraulic conductivity has the dimensions of length/time, or velocity, and is expressed in the units of feet per day.

Transmissivity is a measure of the volume of water which will flow each day through a one foot wide vertical strip of aquifer which extends the fall saturated height of the aquifer. The transmissivity is equal to the product of the hydraulic conductivity and the saturated thickness of the aquifer, and indicates the capacity of the aquifer as a whole to transmit water (Theis, 1935).

The storage coefficient is a dimensionless term defined as the volume of water the aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface (Walton, 1962). The storage coefficients of unconfined aquifers (e.g., water table aquifers), such as the Upper Zone Aquifer in the Flightline Area, usually range from 0.05 to 0.30 (Ferris, et al., 1962). Unconfined aquifers usually have higher values for storage coefficients than confined aquifers, and these higher values reflect that releases from storage represent mostly pore dewatering, whereas in confined aquifers, releases from storage represent the effects of water expansion and aquifer compaction due to changes in fluid pressure (Freeze and Cherry, 1979). The storage term for unconfined aquifers is also known as the specific yield.

Storage and transmissivity are commonly determined by conducting aquifer tests in wells completed in water-bearing units. Aquifer testing may include constant discharge pump tests, variable rate (step) discharge tests, constant drawdown tests, water level recovery tests, and slug tests.

At the Flightline Area, a constant discharge pump test and water-level recovery tests were conducted to determine the hydraulic properties of the geologic units which contain contaminated ground water. In a constant discharge pump test, a well is pumped at a constant rate and water levels are measured for the duration of the test in the pumping well and in the observation wells which penetrate the water-bearing unit. During the recovery test, the change in the water levels in the wells are recorded after cessation of pumping until near static water levels are attained. Graphs of drawdown and recovery versus time after pumping started and stopped are compared to graphs calculated from mathematical aquifer models to estimate the aquifer parameters.

2.0 GEOLOGIC SETTING

The geologic setting of the Flightline Area at Carswell AFB is described in detail in the main body of this report. Specifically, Section 3.3 provides information about the geologic setting, topography, and stratigraphy. Section 3.4 contains a detailed description of the hydrogeology for the Flightline Area. The reader is referred to these sections prior to proceeding with the remainder of this appendix.

The following paragraphs are provided to supply additional information about the subsurface conditions in the area immediately affected by the aquifer tests.

Soil boring data collected during well installation in the vicinity of the aquifer test location has revealed a coarsening downward sequence of lithologies from land surface to bedrock, which is comprised of the Goodland and Walnut Formations.

The deposits from the surface to bedrock (referred to as "Upper Zone" deposits) are generally 30 to 40 feet thick and consist of 10 to 15 feet of fine grained materials (clay and silt) underlain by 20 to 30 feet of sands and gravels. The thickest sequence of coarser grained materials (sands and gravels) is generally oriented in an east to west trend through the Flightline Area, roughly paralleling White Settlement Road. These deposits are unconsolidated and coarsen downward to predominantly limestone and chert gravels at the contact with the underlying bedrock.

Bedrock of the Goodland and Walnut Formations consists of interbedded, fossiliferous, hard limestone and calcareous shale. The thickness of the Goodland and Walnut Formations in the vicinity of the pumping test location is approximately 30-40 feet. The Goodland and Walnut Formations have been dry when sampled during drilling activities in the area, and with the thickness and hardness of the formations they are believed to form an effective confining layer between the Upper Zone water-bearing deposits and the underlying water-bearing sands of the Paluxy Formation.

The water-bearing zone (Upper Zone Aquifer) immediately adjacent to the pumping well (LF04-03) is an unconfined, or water-table, aquifer. The water table as encountered in the subsurface is under atmospheric pressure, and wells completed in the aquifer will reflect the actual water level. This is in opposition to confined aquifers where wells tapping the aquifer may have water levels considerably above the top of the aquifer.

Water levels from wells LF04-02 and LF04-03 were electronically monitored during the pump test and recovery test. The lithologic logs of these wells and well construction data are located in Attachment A.

Well LF04-03, the pumping well, is screened across the lower 14.3 feet of Upper Zone sediments. These sediments are mainly medium grained sand with minor gravels in the upper 10 feet of screened interval, and the lower section of the screen is across predominantly small pebble size gravels (< 10% sand).

Well LF04-02, 50 feet north of the pumping well and the nearest observation well, is screened across similar units as LF04-03. This well also has 14.3 of screen. Again, the screened interval encompasses medium sands, however, the gravel content is not as high near the bottom of the screened interval (approximately 5% gravels) as in LF04-03.

The water table, prior to the start of the aquifer test, occurred approximately 25 feet below land surface in the vicinity of the pump test location. The saturated thickness of the Upper Zone Aquifer was calculated to be 11.7 at the pump well (LF04-03).

In addition to the pump well and near observation well, seven other monitor wells in the vicinity of the pump test location were used as observation wells. These wells are all screened across Upper Zone Aquifer sediments, and vary in distances of 100 to 450 from the pump well (Figure 2-1).

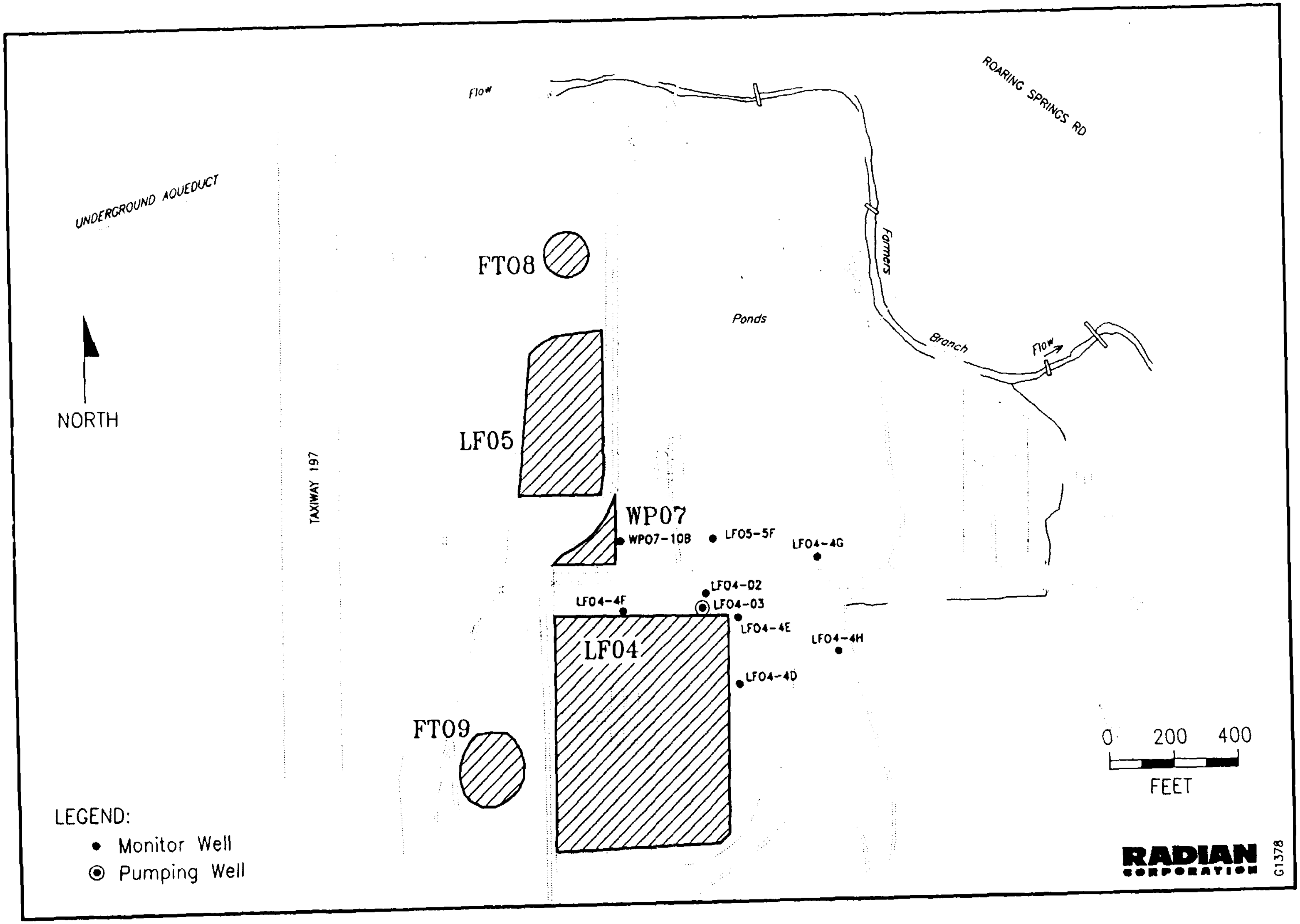

Figure 2-1. Location of Pumping Well and Observation Wells, Flightline Area Pump Test, Carswell AFB, Texas

3.0 FIELD INVESTIGATION

3.1 Pumping Test Procedures

The Flightline Area aquifer pump test was conducted June 21-22, 1990 and ran for 20 hours. The recovery test, which started with the cessation of the pump test, ran for 7 2/3 hours.

3.1.1 Discharge Water

Discharge water produced during the pump test was run through over 300 feet of polyethylene pipe before being routed into the City of Fort Worth sewer system. Pumping rates were measured approximately every hour using a bucket and stopwatch (volumetrically). The temperature, pH, and conductivity of the discharge water was also measured regularly. The discharge of the pump remained constant through the test, with measured discharges (17) varying from 17.9 to 18.7 gallons-per-minute (gpm). The averaged discharge was 18.3 gpm, leading to an approximate total discharge of 22,000 gallons during the pump test.

At the request of the City of Fort Worth Water Department, the discharge water was aerated for removal of volatile organic compounds (VOCs).

Aeration of the pump test discharge water, prior to sanitary sewer discharge, was accomplished with a trailer mounted 125 cfm air compressor. Air from the compressor was routed to a small holding pond which was receiving water from the pumping well. A hole in the top of the holding pond (swimming pool) allowed for discharge of the aerated water to the sewer system.

Periodically during the pump test, water samples going into the holding pond (pre-aeration) and exiting the pond (post-aeration) were collected. These samples were collected in 40 ml VOA vials, filling each approximately 2/3's with water. These water samples were then allowed to sit in the open sun for several hours prior to a headspace analysis for volatile organic content. The time spent in the sun allowed volatile organics in the ground-water samples to volatilize to the overlying air column. The volatile organic content of the air (headspace) was then measured with an HNu photo-ionization detector (PID). This was accomplished by cutting a small slit in the Teflon™ septum in the cap of the vial and quickly inserting the probe of the HNu PID. Table 3-1 summarizes the results of the headspace analyses performed on the discharge water samples from the Flightline Area pump test.

As seen from the table, the aeration of the pump test water prior to discharging to the city sewer system reduced the volatile organic content of the water in every sample analyzed. The average reduction, considering all the analyses, was slightly over 40 percent. The HNu PID is not compound specific, instead measuring the total volatile organic content in the air. The instrument was responding very well, and duplicate (D) analyses performed on the samples from 1630 showed only a three percent relative difference.

3.1.2 Test Types and Measurements

Background water-level data in the pumping well and the near observation well were collected electronically (at 10-minute intervals) for approximately 40 hours with a Hermit electronic data logger prior to the step test. The background data are useful for observing natural trends in the Upper Zone Aquifer water level, such as increases from recharge or decreases due to evapotranspiration. A slight downward trend in water levels, followed by a slight recovery, was observed in wells LF04-02 and LF04-03. The background water level data for the two wells, as well as hydrographs showing the natural water level trends, are included in Attachment B.

A step test was performed prior to the start of the pumping test to establish the optimum pumping rate. The optimum pumping rate for the Flightline Area pumping test set-up was determined to be the full capacity of the submersible pump (Gould 1/2 HP, Model 10 EJ), or approximately 20 gallons per minute. The pump was rated at approximately 25 gpm (with the amount of

TABLE 3-1. HEADSPACE ANALYSIS

Time Sample Taken	HNu Value (ppm) Water Going Into Pool	HNu Value (ppm) Water Going Into Sewer	Time Sample Analyzed	Background HNu Reading
0945	20+	2-3	1515	0.1
1030	4.5	3.8	1525	0.0
1130	4.6	3.3	1530	0.0
1315	9.4	2.2	1535	0.0
1430	11.6	7.9	1910	0.0
1530	10.3	6.0	1912	0.0
1630	10.4	7.3	1915	0.0
1630 (D)	10.3	7.5	1918	0.0
1915	12.0	6.8	2120	0.0

(D) - Denotes duplicate sample

hydraulic head encountered in the pumping well); however, travel of discharge water through over 300 feet of polyethylene pipe before ultimate discharge to the sewer system reduced discharge rates proportionately.

The pump test followed the end of the step test by about 16 hours, and measured water levels had recovered to over 99 percent of their pre-step test level. The 4-inch submersible pump (used in pump and step test) was powered by a 3500 watt portable generator.

During both the pumping and recovery tests, water levels in the pumping well (LF04-03) and the near observation well (LF04-02) were recorded using pressure transducers and an automatic data logger (Hermit Model 1000B). The Hermit collected water-level data for the two wells, for both the pump and recovery test, is included in Attachment C. Water levels were also manually measured in surrounding monitor wells with a calibrated Olympic electric water-level probe. The water-level probe was decontaminated prior to each water-level measurement. The water levels in the pumping well and near observation well were also checked regularly with the Olympic meter to verify the accuracy of the Hermit data logger. The manual water-level measurements are provided in Attachment D. The maximum water-level decline observed in the manually measured observation wells was 0.09 feet (LF04-4E). Hydrographs of the water levels in the observation wells during the pump test are also provided in Attachment D.

As seen from the hydrographs, there appears to be a slight water-level rise around 700 minutes into the pump test. The timing of the water-level rise corresponds with a decrease in barometric pressure. Figure 3-1 shows the barometric pressure plotted with the water levels measured in well LF04-4H. This pressure phenomenon appears to have had a slight effect on the water level of the Upper Zone Aquifer, but the barometric pressure goes back up to roughly the same value as when pumping started by the end of the pump test. The overall trend of water levels does not appear to have been affected significantly by the pressure fluctuations. Unconfined aquifers are naturally less affected by barometric pressure fluctuations than confined aquifers.

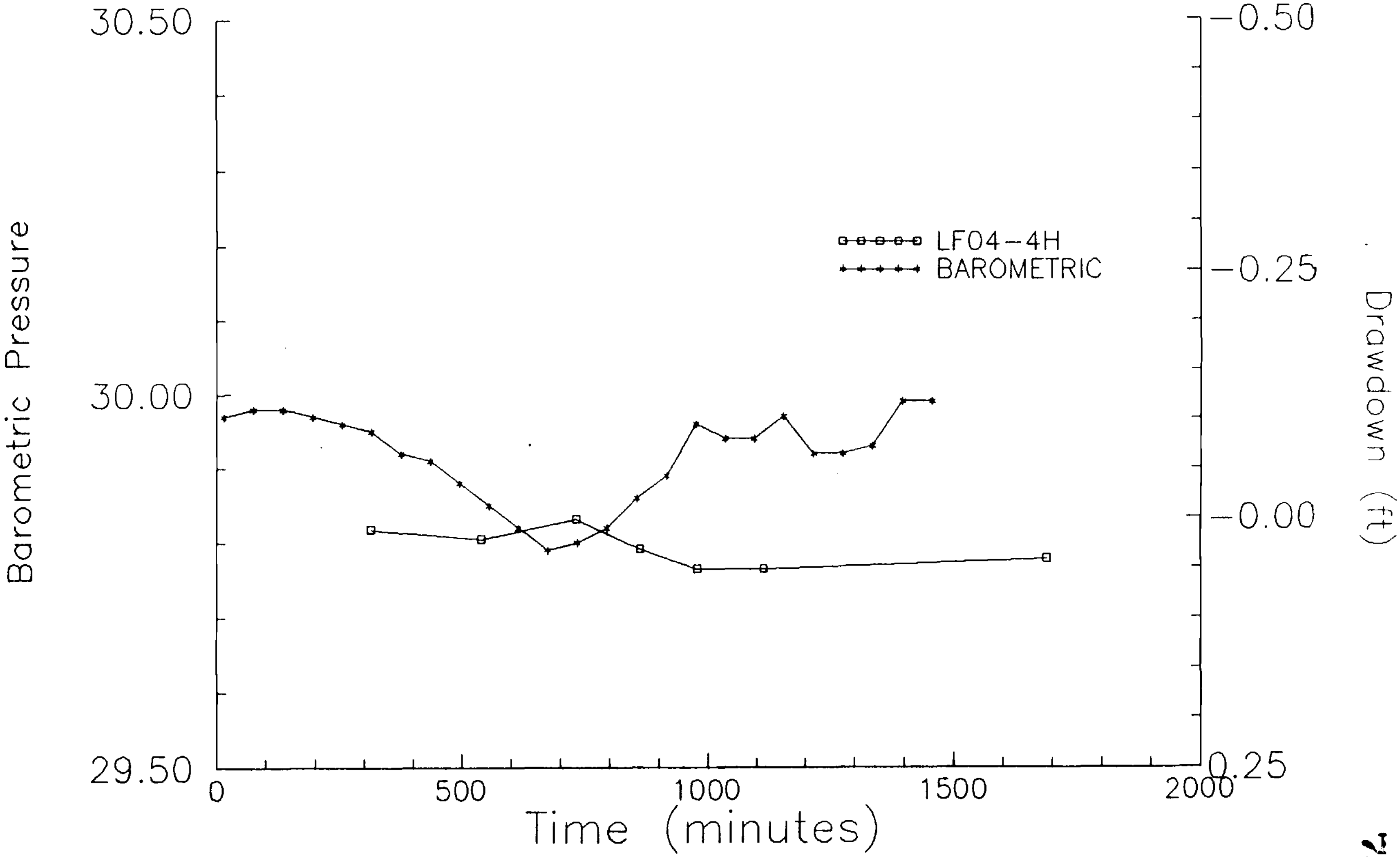

Figure 3-1. Barometric Pressure Effects on Water Level in Monitor Well LF04-4H

4.0 TEST RESULTS

4.1 Analytical Methods and Assumptions

The data obtained during the June 1990 Upper Zone aquifer pumping test were analyzed by several methods. In addition to field plotting of drawdown and distance drawdown measurements, a computer aquifer analysis program was used. The well hydraulics interpretation program used was WHIP™, which has the ability to simulate and analyze both drawdown and recovery tests.

Attempts were initially made to interpret the pump test data using the techniques of Boulton (1963) and Neuman (1975) for unconfined aquifers. These techniques consider the effects of gravity drainage in an unconfined aquifer, which result in a delayed yield of ground water to the well and a corresponding fluctuation in the time-drawdown data curve. As can be seen from Figure 4-1, delayed yield was not pronounced (if evident) in the loglog plot of the near observation well drawdown. Attempts at matching respective portions of the drawdown curve with various Type A and Type B curves met with no success. Therefore, in the analysis of unconfined aquifer data showing no apparent delayed yield, the techniques of Theis and Cooper-Jacob were applied to the data.

The Theis and Cooper-Jacob analyses were used as both field methods and in later data analysis for estimating aquifer parameters. Time versus drawdown for observation wells were plotted on semi-log paper. From this plot, the change in drawdown over a particular log cycle was used in the calculation of aquifer transmissivity and storativity, using the equations:

$$T = \frac{2.3Q}{4\pi\Delta h} \qquad \text{and} \qquad S = \frac{2.25Tt_o}{v^2}$$

where: T = transmissivity
Q = pumping rate
Δh = the drawdown for one log cycle

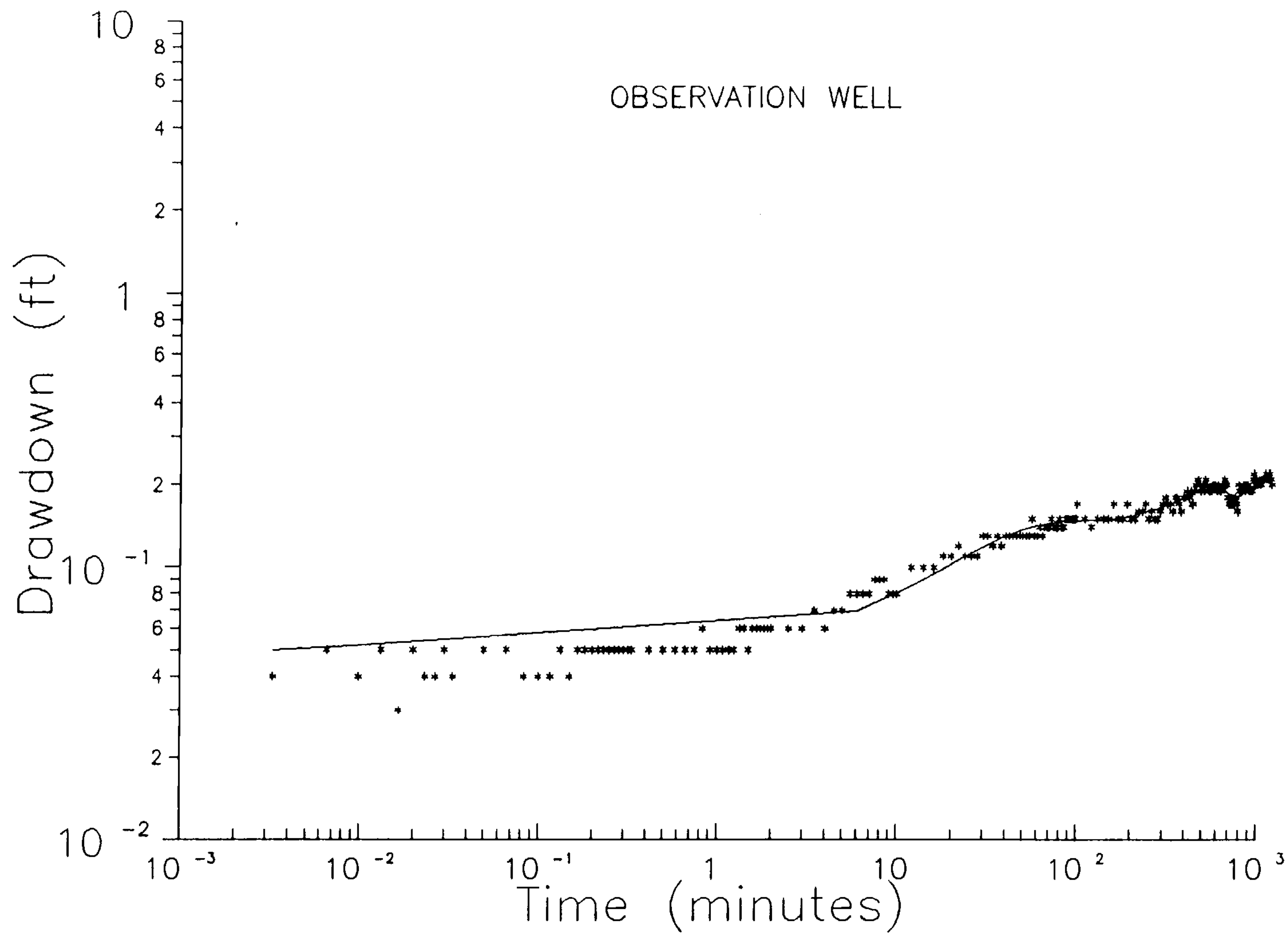

Figure 4-1. Loglog Plot of Observation Well (LF04-02) Drawdown

S - storativity

t_o - time intercept where the drawdown line intercepts the zero drawdown axis

v - radial distance from the pumping well to observation well

The WHIP™ diagnostic procedures also use semilog drawdown (Cooper-Jacob) analyses and Theis recovery analyses to obtain preliminary estimates of the transmissivity and storage coefficient. Theis curves are generated using these values and are graphically compared to the observed data. Portions of the generated curves can be "windowed" so only reliable data are used for the generation of final transmissivity and storage coefficient values.

In addition to standard semilog and loglog plots, the effects of various time transformations on the data as well as first and second derivatives of the drawdowns were performed. Observing the derivative drawdown plots was useful for determining that portion of the test data displaying Theis behavior. Additionally, the Dupuit correction for water table conditions was applied to all computer analyses and the initial estimates of transmissivities and storage coefficients were optimized using an ordinary least squares fitting criterion. This correction minimizes irregularities inherent in field generated data to improve computer aided curve matching techniques and allow greater accuracy in the calculation of aquifer parameters.

Three different computer generated plots and analyses were determined to best represent the Upper Zone aquifer hydraulic properties of transmissivity and storage coefficient. These were the observation well (LF04-02) drawdown and recovery analyses and the pumping well (LF04-03) recovery analysis.

Seven additional monitor wells were measured for response to the pumping well and there was little if any noted.

4.2 Water Level Behavior in Pumping Well and Near Observation Well

The observed maximum drawdown was 3.58 feet in the pumping well and 0.20 feet in the near observation well, located 50 feet north of the pumping well.

4.3 Results

The results of the computer-assisted pump test analyses are presented in Table 4-1. The drawdown and recovery curves for the observation well were analyzed as well as the recovery curve for the pumping well. The average values for the parameters of transmissivity and hydraulic conductivity and a value for storage coefficient are shown on the table. The averaged values are representative of the types of aquifer materials encountered (clean sands and gravels). The WHIP™ generated plots for the analyses are provided in Attachment E.

TABLE 4-1. SUMMARY OF AQUIFER PUMPING TEST RESULTS, FLIGHTLINE AREA, CARSWELL AFB, TEXAS (JUNE, 1990)

Well Number	Type of Test Analyses	Distance From Pumping Well (ft)	Transmissivity	Hydraulic Conductivity	Storage Coefficient (Dimensionless)
LF04-02	Drawdown	50	9771 ft^2/day	835 ft/day (2.9×10^{-1} cm/sec)	1.2×10^{-2}
	Recovery	50	8260 ft^2/day	705 ft/day (2.5×10^{-1} cm/sec)	
LF04-03	Recovery	Pumping Well	9501 ft^2/day	812 ft/day (2.9×10^{-1} cm/sec)	
		Average Values	9177 ft^2/day	784 ft/day (2.8×10^{-1} cm/sec)	1.2×10^{-2}

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5.0 REFERENCES

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DRILLING LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX	SHEET 1 OF 2 SHEETS

1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 37.7 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 14
4. HOLE NO.: LF04-02	11. ELEVATION GROUND WATER: 597.45 ft MSL (6/18/90)
5. NAME OF GEOLOGIST: S. E. Fain	12. DATE HOLE ESTABLISHED: 3/28/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 621.00 ft MSL
X: 2020510.50 Y: 397732.54	14. BACKGROUND:
	15. MEASURING POINT ELEVATION: 623.68 ft MSL

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLLR	Clay: Dark brown, silty, firm, roots, damp, carbonaceous staining.	Full samplers unles noted.
2			U/CLLR	Clay: As above; at 3.0 ft. going to orange/brown, silty clay with 5 - 10% calcareous material.	
4			U/CLLR	Clay: As above.	1.5 ft. Recovery
6			U/CLLR	Clay: Orange/brown, very silty, minor very fine grained sand, stiff, calcareous nodules, carboaceous streaking.	
8			U/CLLR	Clay: As above, increasing calcareous material to 30%.	
11			U/SDGR	Sand and Gravel: Orange, very poorly sorted, cohesive, clayey, silty, damp, abundant calcareous material.	
13			U/SDLR	Sand: Orange, fine grained, minor larger sizes to coarse, slightly clayey and silty, damp.	
13.5			U/SDLR	Sand: As above, increasing coarseness with depth, 5 - 10% small gravels.	
16.5			U/SDLR	Sand: As above, gravelly; changing to tan, fine to medium grained, loose, quartzose at 18.0 ft., damp.	
18.5			U/SDLR	Sand: As above, well sorted, medium grained, damp; 0.4 ft gravelly zone at 21.5 - 21.9 ft.	3.5 ft. Recovery

DRILLING LOG | RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX | SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 37.7 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 14
4. HOLE NO.: LF04-02	11. ELEVATION GROUND WATER: 597.45 ft MSL (6/18/90)
5. NAME OF GEOLOGIST: S. E. Fain	12. DATE HOLE ESTABLISHED: 3/28/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 621.00 ft MSL
X: 2020510.50 Y: 397732.54	14. BACKGROUND:
	15. MEASURING POINT ELEVATION: 623.68 ft MSL

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
23.5			U/SDLR	Sand: Orange/tan, medium grained, well sorted, subround, >90% quartz; 0.3 ft. gravelly zone at 27 ft., saturated at 28 ft.	4.0 ft. Recovery
28.5			U/SDLR	Sand: As above, 1-3% granule size gravel.	W. L. measured at 28.1 ft. BLS, 5.0 ft. Recovery
33.5			U/SDLR	Sand: Tan, medium grained, quartzose, loose, wet, 5% gravels to 25 mm.	3.7 ft. Recovery.
37			U/MARL	Limestone: Marly, weathered sand and gravel intermixed, fissile.	T.D. = 37.7 ft.

DRILLING LOG / RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX / SHEET 1 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 37.6 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 14
4. HOLE NO.: LF04-03	11. ELEVATION GROUND WATER: 597.58 ft MSL (6/18/90)
5. NAME OF GEOLOGIST: S. B. Blount, S. E. Fain	12. DATE HOLE ESTABLISHED: 3/20/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 620.50 ft MSL
X: 2020506.79 Y: 397683.46	14. BACKGROUND:
	15. MEASURING POINT ELEVATION: 623.25 ft MSL

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
0			U/CLAY	Clay: Brown, soft to firm, semi-plastic, with fine rootlets and minor carbonaceous streaking and particles, moist to wet.	Full recovery unless otherwise indicated.
2			U/CLAY	Clay: As above, firm to stiff (stiffens to base), minor calcareous debris, more abundant carbonaceous staining, very stiff; 3.8 - 4.0 ft.	Too stiff to cut.
4			U/CLLR	Clay: Orange/brown at 4.1 ft; brittle, damp, abundant calcareous debris, slickensided, calichified with some authigenic mineralization (crystals of CaCO3 in shell frags.); very hard, silty.	Hard pushing.
6			U/CLLR	Clay: As above, very stiff, slightly sandy and silty.	
8			U/CLLR	Clay: As above, few large CaCO3 pebbles (25 mm), increasing clacareous material with depth, very fine grained sand.	1 ft. recovery, ST. Rig broken. Continue after repairs.
10			U/CLLR	Clay: Orange/brown, silty, cohesive, damp, > 30% calcareous material, stiff.	Caliche layer at 12 ft., drilling through.
12.1			U/SDFN	Sand: Orange, fine grained, loose, damp, quartzose, well sorted; at 14.3 ft. sharp change to tan, very fine grained sand, heavily oxidized in laminae.	
14.5			U/SAND	Sand: Orange, fine to medium grained, quartzose, damp, loose; gravelly seam 15 - 15.5 ft.	3 ft. Recovery.
19.5			U/SDLR	Sand: Orange/tan, fine to medium grained, damp, loose, subround, > 90% quartz, 1 - 3% small gravel and shells.	4 ft. Recovery.

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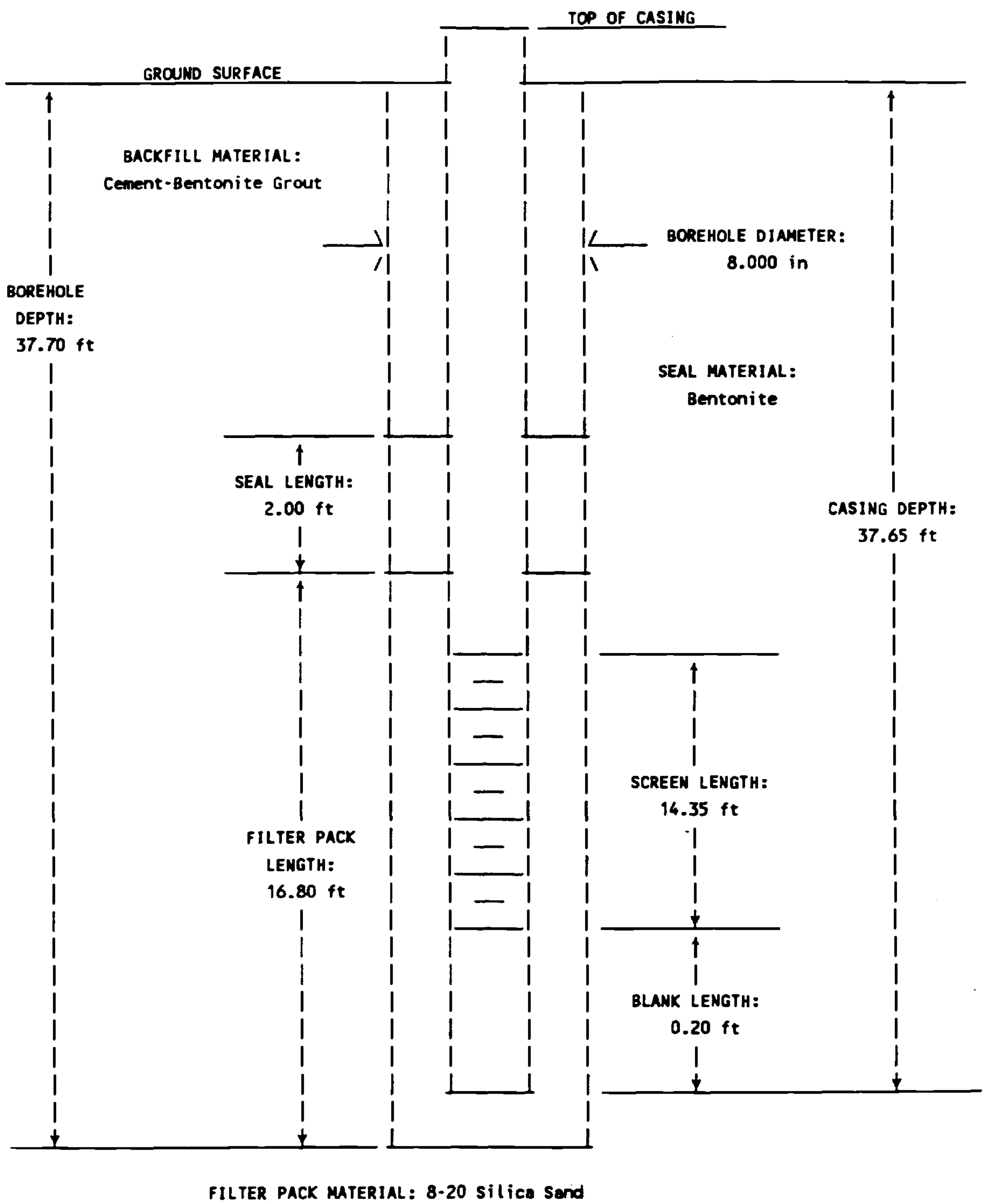
DRILLING LOG | RADIAN CORPORATION	INSTALLATION: CARSWELL AFB, TX | SHEET 2 OF 2 SHEETS
1. PROJECT: CARSWELL AFB, IRP PHASE II STAGE 2	7. TOTAL DEPTH OF HOLE: 37.6 ft BGL
	8. DATUM FOR ELEVATION SHOWN: sea level
2. LOCATION: Flightline Area	9. MANUFACTURER'S DESIGNATION OF DRILL: Mobile Drill B-61
3. DRILLING AGENCY: Environmental Drillers, Inc.	10. NO. OF SAMPLES TAKEN: 14
4. HOLE NO.: LF04-03	11. ELEVATION GROUND WATER: 597.58 ft MSL (6/18/90)
5. NAME OF GEOLOGIST: S. B. Blount, S. E. Fain	12. DATE HOLE ESTABLISHED: 3/20/90
6. COORDINATES OF HOLE:	13. SURFACE ELEVATION: 620.50 ft MSL
X: 2020506.79 Y: 397683.46	14. BACKGROUND:
	15. MEASURING POINT ELEVATION: 623.25 ft MSL

Depth (Ft.)	Graphic Log	Blow Count	Soil Class/Code	Visual Description	Remarks
24.5			U/SDLR	Sand: Orange/tan, fine to medium grained, wet, loose, 0.5 ft. gravelly zone at 27 ft., quartzose; at 30 ft.	W. L. measured at 26.3 ft. Bls. 2.6 ft. recovery.
29.5			U/SDLR	Sand: As above, saturated.	3.2 ft. Recovery.
32			U/GRVL	Gravel: Varicolored, up to pebble size (30 mm), shells, <10% sand, saturated.	
34.5			U/GRVL	Gravel: As above, mainly small pebble size (5 - 10 mm), shells, subangular to subrounded, large percentage of chert.	
37.5		50	U/MARL	Marl: Chalky gray, indurated, oxidation stained throughout.	Sampler refusal at 37.5 ft., drove 1 1/2 in. S.S. 50 blows = 1 in.; T.D. = 37.6 ft.

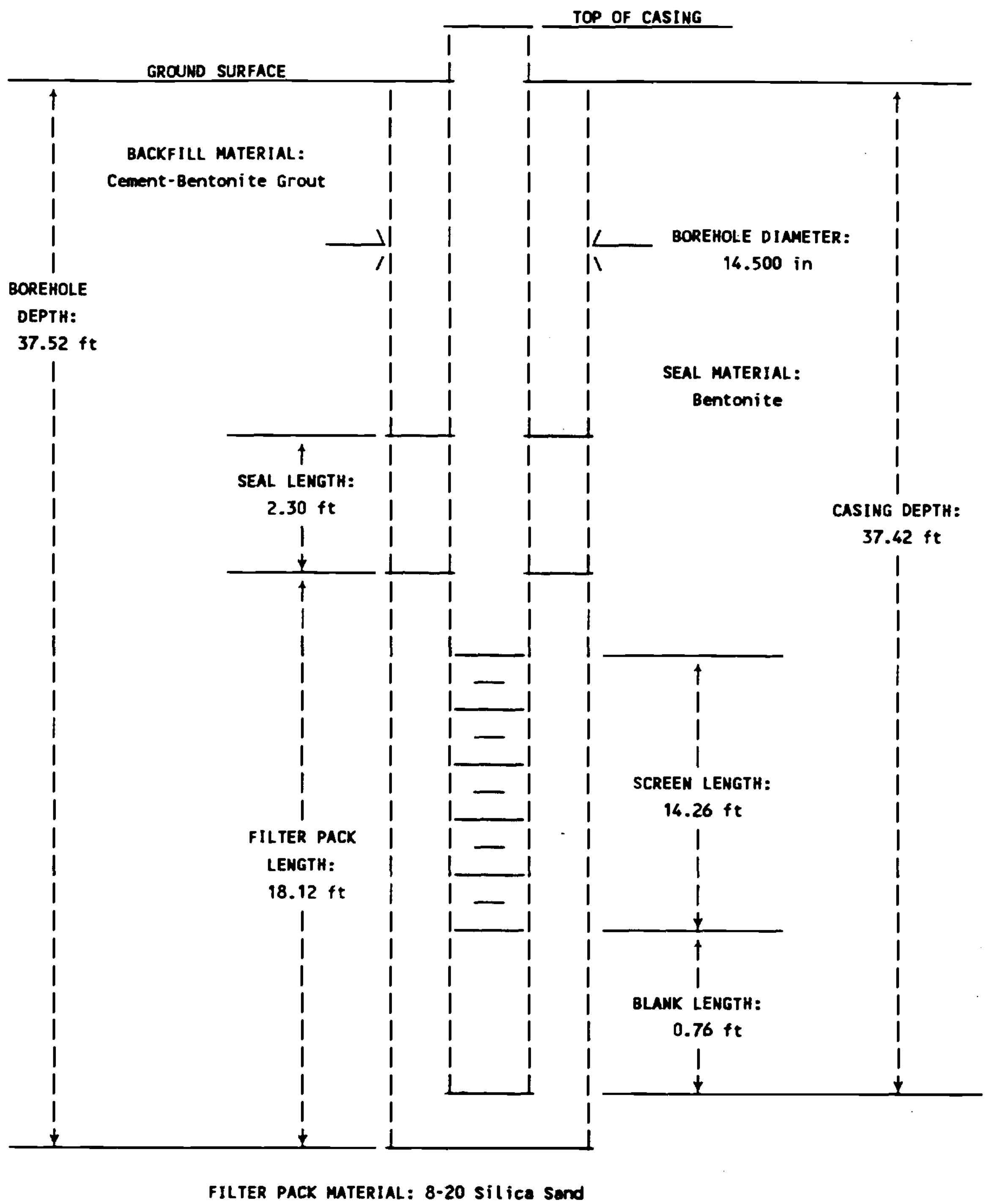
WELL COMPLETION LOG	RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB		9. INSTALLATION DATE: 3/28/90
		10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF04		11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation		12. SEAL END DEPTH: 20.90 ft
4. WELL NO.: LF04-02		13. MEAS. POINT ELEV.: 623.68 ft MSL
5. WELL OWNER: U.S. AIR FORCE		14. CASING DIAMETER: 2.00 in
6. WELL TYPE CLASS: MONITORING WELL		15. CASING MATERIAL: Schedule 40 PVC
7. FORMATION OF COMPLETION:		16. SCREEN BEGIN. DEPTH: 23.10 ft
8. LOCATION TYPE: WL		17. SCREEN SLOT SIZE: 0.02 in

18. REMARKS: 1-10'x2"x0.02" Screen,3-10'x2" Risers,1-Cut piece (~0.4'),1-Locking Cap, 1-bottom Cap



WELL COMPLETION LOG / RADIAN CORPORATION	INSTALLATION: CARSWELL AFB
1. PROJECT: IRP PHASE II STAGE 2, CARSWELL AFB	9. INSTALLATION DATE: 4/3/90
	10. WELL COMPLETION METHOD: GRAVEL PACK W/SCREEN
2. LOCATION: Site LF04	11. ZONE OF COMPLETION: Aquifer
3. INSTALLING CO.: Radian Corporation	12. SEAL END DEPTH: 19.40 ft
4. WELL NO.: LF04-03	13. MEAS. POINT ELEV.: 623.25 ft MSL
5. WELL OWNER: U.S. AIR FORCE	14. CASING DIAMETER: 6.00 in
6. WELL TYPE CLASS: MONITORING WELL	15. CASING MATERIAL: Schedule 80 PVC
7. FORMATION OF COMPLETION:	16. SCREEN BEGIN. DEPTH: 22.40 ft
8. LOCATION TYPE: WL	17. SCREEN SLOT SIZE: 0.02 in

18. REMARKS: 1x10'x6" PVC 0.020 screen, 1x5'x6" screen, 2x10'x6" PVC riser, 1x5'x6" riser.



ATTACHMENT B

Background Water-Level Data and Hydrographs

... - Pumping we

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Time minutes		Time minutes		Time minutes		Time minutes	
0	0	600	-0.05	1200	-0.06	1800	-0.08
10	-0.01	610	-0.05	1210	-0.07	1810	-0.08
20	-0.01	620	-0.05	1220	-0.07	1820	-0.08
30	-0.02	630	-0.05	1230	-0.07	1830	-0.08
40	-0.02	640	-0.05	1240	-0.06	1840	-0.07
50	-0.02	650	-0.05	1250	-0.06	1850	-0.08
60	-0.03	660	-0.05	1260	-0.06	1860	-0.08
70	-0.03	670	-0.05	1270	-0.07	1870	-0.08
80	-0.03	680	-0.04	1280	-0.07	1880	-0.08
90	-0.03	690	-0.04	1290	-0.07	1890	-0.08
100	-0.03	700	-0.03	1300	-0.06	1900	-0.08
110	-0.03	710	-0.03	1310	-0.08	1910	-0.08
120	-0.03	720	-0.03	1320	-0.07	1920	-0.08
130	-0.03	730	-0.05	1330	-0.06	1930	-0.08
140	-0.03	740	-0.03	1340	-0.08	1940	-0.08
150	-0.03	750	-0.03	1350	-0.08	1950	-0.08
160	-0.03	760	-0.03	1360	-0.08	1960	-0.08
170	-0.03	770	-0.03	1370	-0.08	1970	-0.08
180	-0.04	780	-0.03	1380	-0.09	1980	-0.08
190	-0.04	790	-0.03	1390	-0.08	1990	-0.08
200	-0.03	800	-0.03	1400	-0.08	2000	-0.08
210	-0.04	810	-0.03	1410	-0.08	2010	-0.08
220	-0.04	820	-0.03	1420	-0.09	2020	-0.08
230	-0.04	830	-0.03	1430	-0.08	2030	-0.08
240	-0.04	840	-0.03	1440	-0.09	2040	-0.08
250	-0.04	850	-0.03	1450	-0.09	2050	-0.08
260	-0.04	860	-0.03	1460	-0.09	2060	-0.07
270	-0.04	870	-0.03	1470	-0.09	2070	-0.07
280	-0.04	880	-0.03	1480	-0.09	2080	-0.07
290	-0.05	890	-0.03	1490	-0.09	2090	-0.06
300	-0.04	900	-0.03	1500	-0.09	2100	-0.07
310	-0.04	910	-0.03	1510	-0.09	2110	-0.06
320	-0.05	920	-0.03	1520	-0.09	2120	-0.06
330	-0.05	930	-0.03	1530	-0.09	2130	-0.06
340	-0.05	940	-0.03	1540	-0.08	2140	-0.06
350	-0.05	950	-0.03	1550	-0.08	2150	-0.06
360	-0.05	960	-0.03	1560	-0.08	2160	-0.06
370	-0.05	970	-0.05	1570	-0.08	2170	-0.06
380	-0.05	980	-0.03	1580	-0.08	2180	-0.06
390	-0.05	990	-0.04	1590	-0.08	2190	-0.06
400	-0.05	1000	-0.04	1600	-0.07	2200	-0.05
410	-0.05	1010	-0.05	1610	-0.07	2210	-0.05
420	-0.05	1020	-0.05	1620	-0.07	2220	-0.05
430	-0.05	1030	-0.05	1630	-0.07	2230	-0.06
440	-0.05	1040	-0.05	1640	-0.07	2240	-0.06
450	-0.05	1050	-0.05	1650	-0.07	2250	-0.06
460	-0.05	1060	-0.06	1660	-0.07	2260	-0.06
470	-0.05	1070	-0.05	1670	-0.07	2270	-0.06
480	-0.05	1080	-0.06	1680	-0.07	2280	-0.06
490	-0.05	1090	-0.06	1690	-0.07	2290	-0.05
500	-0.05	1100	-0.06	1700	-0.08	2300	-0.05
510	-0.05	1110	-0.06	1710	-0.07	2310	-0.05
520	-0.05	1120	-0.06	1720	-0.08	2320	-0.06
530	-0.05	1130	-0.05	1730	-0.08	2330	-0.05
540	-0.05	1140	-0.06	1740	-0.07	2340	-0.05
550	-0.05	1150	-0.06	1750	-0.08	2350	-0.06
560	-0.05	1160	-0.06	1760	-0.08	2360	-0.06
570	-0.05	1170	-0.06	1770	-0.07	2370	-0.06
580	-0.05	1180	-0.05	1780	-0.08		
590	-0.05	1190	-0.06	1790	-0.08		

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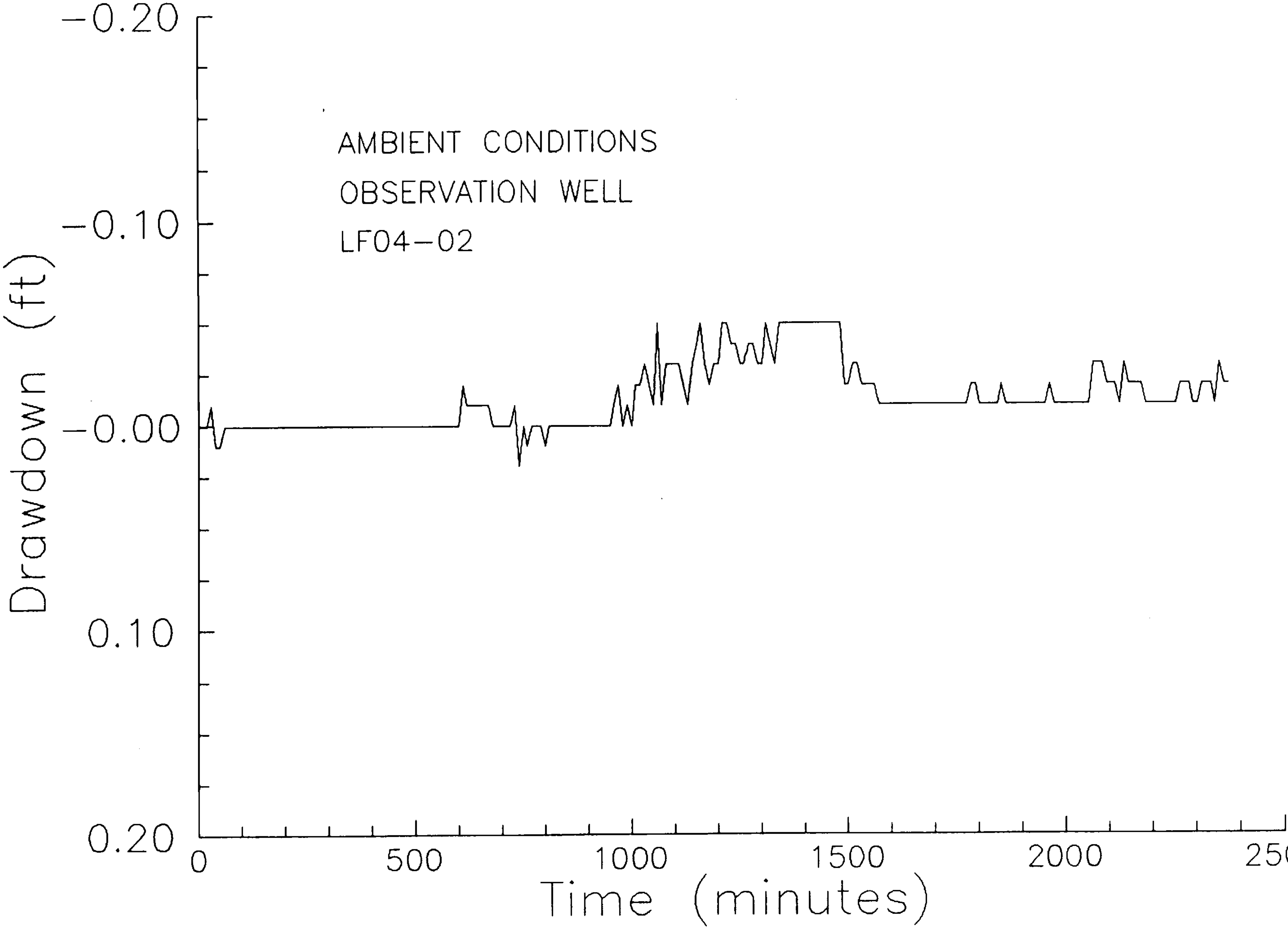
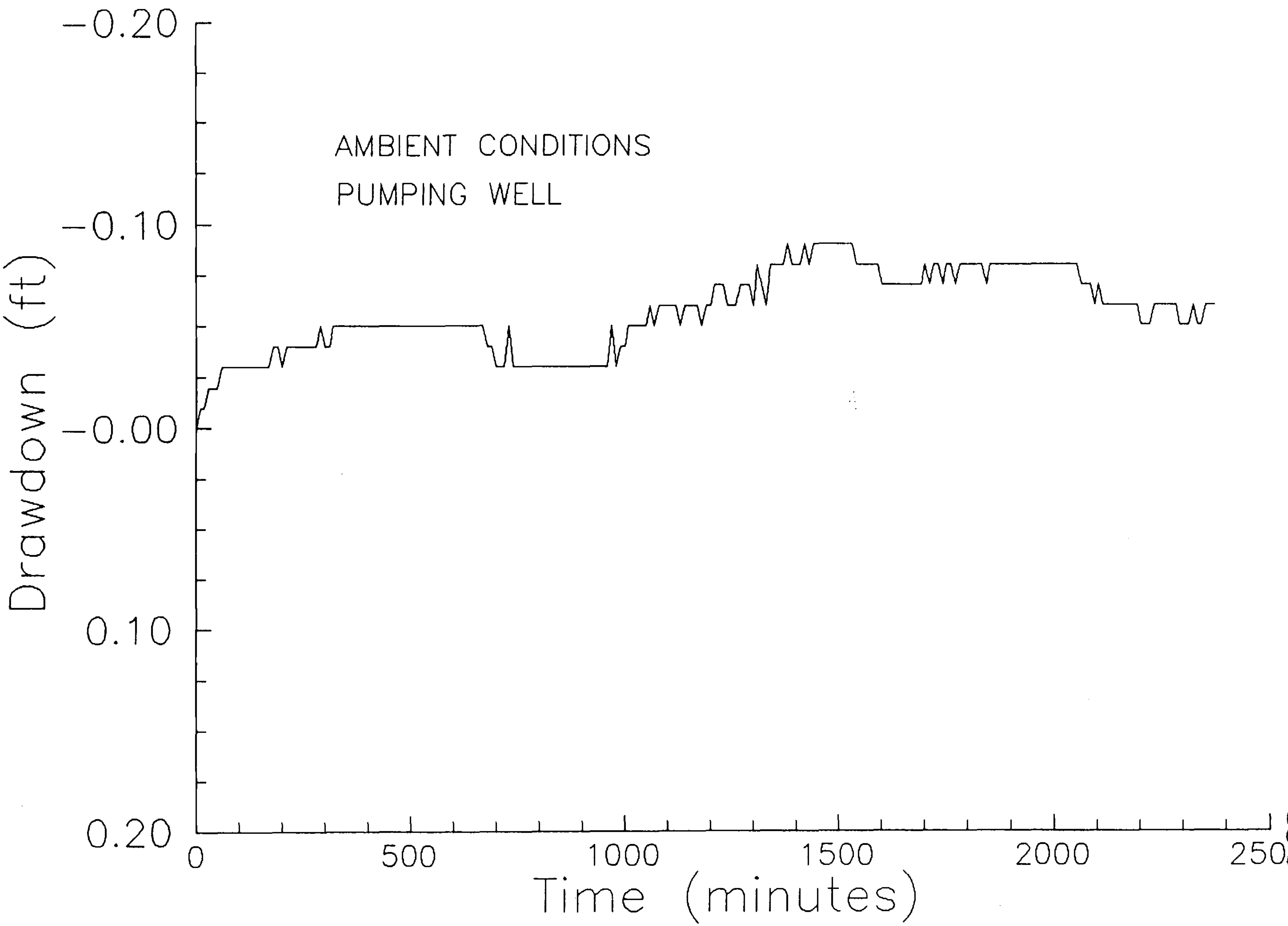
Time minutes		Time minutes		Time minutes		Time minutes	
0	0	600	0	1200	-0.03	1800	-0.01
10	0	610	-0.02	1210	-0.05	1810	-0.01
20	0	620	-0.01	1220	-0.05	1820	-0.01
30	-0.01	630	-0.01	1230	-0.04	1830	-0.01
40	0.01	640	-0.01	1240	-0.04	1840	-0.01
50	0.01	650	-0.01	1250	-0.03	1850	-0.02
60	0	660	-0.01	1260	-0.03	1860	-0.01
70	0	670	-0.01	1270	-0.04	1870	-0.01
80	0	680	0	1280	-0.04	1880	-0.01
90	0	690	0	1290	-0.03	1890	-0.01
100	0	700	0	1300	-0.03	1900	-0.01
110	0	710	0	1310	-0.05	1910	-0.01
120	0	720	0	1320	-0.04	1920	-0.01
130	0	730	-0.01	1330	-0.03	1930	-0.01
140	0	740	0.02	1340	-0.05	1940	-0.01
150	0	750	0	1350	-0.05	1950	-0.01
160	0	760	0.01	1360	-0.05	1960	-0.02
170	0	770	0	1370	-0.05	1970	-0.01
180	0	780	0	1380	-0.05	1980	-0.01
190	0	790	0	1390	-0.05	1990	-0.01
200	0	800	0.01	1400	-0.05	2000	-0.01
210	0	810	0	1410	-0.05	2010	-0.01
220	0	820	0	1420	-0.05	2020	-0.01
230	0	830	0	1430	-0.05	2030	-0.01
240	0	840	0	1440	-0.05	2040	-0.01
250	0	850	0	1450	-0.05	2050	-0.01
260	0	860	0	1460	-0.05	2060	-0.03
270	0	870	0	1470	-0.05	2070	-0.03
280	0	880	0	1480	-0.05	2080	-0.03
290	0	890	0	1490	-0.02	2090	-0.02
300	0	900	0	1500	-0.02	2100	-0.02
310	0	910	0	1510	-0.03	2110	-0.02
320	0	920	0	1520	-0.03	2120	-0.01
330	0	930	0	1530	-0.02	2130	-0.03
340	0	940	0	1540	-0.02	2140	-0.02
350	0	950	0	1550	-0.02	2150	-0.02
360	0	960	-0.01	1560	-0.02	2160	-0.02
370	0	970	-0.02	1570	-0.01	2170	-0.02
380	0	980	0	1580	-0.01	2180	-0.01
390	0	990	-0.01	1590	-0.01	2190	-0.01
400	0	1000	0	1600	-0.01	2200	-0.01
410	0	1010	-0.02	1610	-0.01	2210	-0.01
420	0	1020	-0.02	1620	-0.01	2220	-0.01
430	0	1030	-0.03	1630	-0.01	2230	-0.01
440	0	1040	-0.02	1640	-0.01	2240	-0.01
450	0	1050	-0.01	1650	-0.01	2250	-0.01
460	0	1060	-0.05	1660	-0.01	2260	-0.02
470	0	1070	-0.01	1670	-0.01	2270	-0.02
480	0	1080	-0.03	1680	-0.01	2280	-0.02
490	0	1090	-0.03	1690	-0.01	2290	-0.01
500	0	1100	-0.03	1700	-0.01	2300	-0.01
510	0	1110	-0.03	1710	-0.01	2310	-0.02
520	0	1120	-0.02	1720	-0.01	2320	-0.02
530	0	1130	-0.01	1730	-0.01	2330	-0.02
540	0	1140	-0.03	1740	-0.01	2340	-0.01
550	0	1150	-0.04	1750	-0.01	2350	-0.03
560	0	1160	-0.05	1760	-0.01	2360	-0.02
570	0	1170	-0.03	1770	-0.01	2370	-0.02
580	0	1180	-0.02	1780	-0.02		
590	0	1190	-0.03	1790	-0.02		


AMBIENT CONDITIONS
OBSERVATION WELL
LF04-02
Drawdown (ft)
-0.20
-0.10
-0.00
0.10
0.20
0
500
1000
1500
2000
2500
Time (minutes)

73 391


AMBIENT CONDITIONS
PUMPING WELL
Drawdown (ft)
-0.20
-0.10
-0.00
0.10
0.20
Time (minutes)
0
500
1000
1500
2000
2500

ATTACHMENT C

Hermit Collected Water-Level Data for
Pump and Recovery Tests

Pumping well drawdown - Pump test

72 395

Time minutes	Drawdown ft.	Time minutes	Drawdown ft.	Time minutes	Drawdown ft.	Time minutes	Drawdown ft.
0.0000	0.58	5.5	3.65	110	3.94	660	4.05
0.0033	0.42	6.0	3.67	120	3.94	670	4.03
0.0066	0.50	6.5	3.67	130	3.95	680	4.05
0.0099	0.51	7.0	3.69	140	3.95	690	4.06
0.0133	0.54	7.5	3.70	150	3.95	700	4.05
0.0166	0.63	8.0	3.70	160	3.97	710	4.06
0.0200	0.63	8.5	3.71	170	3.97	720	4.05
0.0233	0.65	9.0	3.72	180	3.96	730	4.05
0.0266	0.68	9.5	3.72	190	3.98	740	4.06
0.0300	0.71	10	3.73	200	3.96	750	4.05
0.0333	0.75	12	3.75	210	3.97	760	4.05
0.0500	0.88	14	3.77	220	3.97	770	4.06
0.0666	0.98	16	3.78	230	3.98	780	4.06
0.0833	1.09	18	3.79	240	3.99	790	4.07
0.1000	1.17	20	3.81	250	3.98	800	4.07
0.1166	1.26	22	3.82	260	3.98	810	4.06
0.1333	1.34	24	3.82	270	3.98	820	4.06
0.1500	1.40	26	3.82	280	4.00	830	4.06
0.1666	1.47	28	3.84	290	3.99	840	4.07
0.1833	1.54	30	3.84	300	4.00	850	4.07
0.2000	1.59	32	3.85	310	4.01	860	4.07
0.2166	1.65	34	3.86	320	4.01	870	4.07
0.2333	1.70	36	3.86	330	4.01	880	4.07
0.2500	1.76	38	3.86	340	4.01	890	4.07
0.2666	1.82	40	3.86	350	4.01	900	4.08
0.2833	1.85	42	3.87	360	4.01	910	4.08
0.3000	1.90	44	3.86	370	4.01	920	4.08
0.3166	1.94	46	3.88	380	4.02	930	4.08
0.3333	1.99	48	3.87	390	4.02	940	4.08
0.4167	2.16	50	3.87	400	4.02	950	4.09
0.5000	2.30	52	3.88	410	4.03	960	4.13
0.5833	2.42	54	3.88	420	4.01	970	4.11
0.6667	2.50	56	3.88	430	4.02	980	4.09
0.7500	2.57	58	3.88	440	4.03	990	4.08
0.8333	2.62	60	3.89	450	4.03	1000	4.07
0.9167	2.69	62	3.88	460	4.04	1010	4.07
1.0000	2.74	64	3.88	470	4.03	1020	4.10
1.0833	2.80	66	3.88	480	4.03	1030	4.09
1.1667	2.85	68	3.89	490	4.04	1040	4.08
1.2500	2.91	70	3.89	500	4.04	1050	4.08
1.3333	2.96	72	3.89	510	4.03	1060	4.10
1.4166	3.01	74	3.89	520	4.05	1070	4.09
1.5000	3.05	76	3.90	530	4.05	1080	4.08
1.5833	3.10	78	3.91	540	4.03	1090	4.09
1.6667	3.14	80	3.89	550	4.05	1100	4.09
1.7500	3.17	82	3.91	560	4.04	1110	4.12
1.8333	3.20	84	3.91	570	4.04	1120	4.11
1.9167	3.24	86	3.91	580	4.05	1130	4.10
2.0	3.27	88	3.91	590	4.05	1140	4.10
2.5	3.41	90	3.92	600	4.03	1150	4.10
3.0	3.50	92	3.92	610	4.04	1160	4.12
3.5	3.56	94	3.93	620	4.04	1170	4.10
4.0	3.59	96	3.93	630	4.04	1180	4.10
4.5	3.61	98	3.93	640	4.05	1190	4.09
5.0	3.64	100	3.93	650	4.03	1200	4.08

Observation well drawdown - Pump test

Time minutes	Drawdown ft.	Time minutes	Drawdown ft.	Time minutes	Drawdown ft.	Time minutes	Drawdown ft.
0.0000	0.05	5.5	0.08	110	0.15	660	0.19
0.0033	0.04	6.0	0.08	120	0.14	670	0.18
0.0066	0.05	6.5	0.08	130	0.15	680	0.18
0.0099	0.04	7.0	0.08	140	0.15	690	0.19
0.0133	0.05	7.5	0.09	150	0.15	700	0.18
0.0166	0.03	8.0	0.09	160	0.17	710	0.18
0.0200	0.05	8.5	0.09	170	0.15	720	0.19
0.0233	0.04	9.0	0.08	180	0.15	730	0.19
0.0266	0.04	9.5	0.08	190	0.17	740	0.2
0.0300	0.05	10	0.08	200	0.15	750	0.19
0.0333	0.04	12	0.1	210	0.15	760	0.2
0.0500	0.05	14	0.1	220	0.16	770	0.19
0.0666	0.05	16	0.1	230	0.16	780	0.18
0.0833	0.04	18	0.11	240	0.17	790	0.22
0.1000	0.04	20	0.11	250	0.15	800	0.22
0.1166	0.04	22	0.12	260	0.16	810	0.22
0.1333	0.05	24	0.11	270	0.15	820	0.22
0.1500	0.04	26	0.11	280	0.15	830	0.22
0.1666	0.05	28	0.11	290	0.16	840	0.23
0.1833	0.05	30	0.13	300	0.16	850	0.23
0.2000	0.05	32	0.13	310	0.17	860	0.22
0.2166	0.05	34	0.12	320	0.16	870	0.23
0.2333	0.05	36	0.13	330	0.16	880	0.23
0.2500	0.05	38	0.12	340	0.15	890	0.23
0.2666	0.05	40	0.13	350	0.17	900	0.23
0.2833	0.05	42	0.13	360	0.17	910	0.23
0.3000	0.05	44	0.13	370	0.16	920	0.23
0.3166	0.05	46	0.13	380	0.15	930	0.23
0.3333	0.05	48	0.13	390	0.17	940	0.23
0.4167	0.05	50	0.13	400	0.17	950	0.25
0.5000	0.05	52	0.13	410	0.17	960	0.26
0.5833	0.05	54	0.13	420	0.16	970	0.25
0.6667	0.05	56	0.15	430	0.17	980	0.24
0.7500	0.05	58	0.13	440	0.15	990	0.25
0.8333	0.06	60	0.13	450	0.17	1000	0.24
0.9167	0.05	62	0.14	460	0.18	1010	0.24
1.0000	0.05	64	0.13	470	0.19	1020	0.25
1.0833	0.05	66	0.14	480	0.18	1030	0.24
1.1667	0.05	68	0.14	490	0.17	1040	0.25
1.2500	0.05	70	0.14	500	0.18	1050	0.24
1.3333	0.06	72	0.15	510	0.17	1060	0.25
1.4166	0.06	74	0.14	520	0.19	1070	0.25
1.5000	0.05	76	0.14	530	0.18	1080	0.25
1.5833	0.06	78	0.14	540	0.17	1090	0.25
1.6667	0.06	80	0.15	550	0.17	1100	0.25
1.7500	0.06	82	0.14	560	0.17	1110	0.26
1.8333	0.06	84	0.14	570	0.18	1120	0.25
1.9167	0.06	86	0.15	580	0.18	1130	0.25
2.0	0.06	88	0.15	590	0.18	1140	0.25
2.5	0.06	90	0.15	600	0.17	1150	0.25
3.0	0.06	92	0.15	610	0.18	1160	0.26
3.5	0.07	94	0.15	620	0.17	1170	0.26
4.0	0.06	96	0.15	630	0.17	1180	0.25
4.5	0.07	98	0.15	640	0.18	1190	0.25
5.0	0.07	100	0.17	650	0.18	1200	0.24

Pumping well recovery test

Time (minutes)	Drawdown (Ft)	Time (minutes)	Drawdown (Ft)	Time (minutes)	Drawdown (Ft)
0.0000	4.00	2.0	0.88	76	0.58
0.0033	4.01	2.5	0.84	78	0.58
0.0066	3.98	3.0	0.82	80	0.58
0.0099	3.95	3.5	0.80	82	0.58
0.0133	3.58	4.0	0.79	84	0.58
0.0166	3.84	4.5	0.77	86	0.58
0.0200	3.86	5.0	0.76	88	0.58
0.0233	3.81	5.5	0.75	90	0.58
0.0266	3.77	6.0	0.74	92	0.57
0.0300	3.74	6.5	0.73	94	0.57
0.0333	3.70	7.0	0.72	96	0.57
0.0500	3.56	7.5	0.72	98	0.57
0.0666	3.42	8.0	0.71	100	0.57
0.0833	3.31	8.5	0.70	110	0.56
0.1000	3.22	9.0	0.70	120	0.56
0.1166	3.17	9.5	0.70	130	0.56
0.1333	3.12	10	0.69	140	0.55
0.1500	3.08	12	0.68	150	0.55
0.1666	3.03	14	0.67	160	0.54
0.1833	2.98	16	0.66	170	0.54
0.2000	2.93	18	0.66	180	0.54
0.2166	2.88	20	0.65	190	0.54
0.2333	2.83	22	0.65	200	0.54
0.2500	2.78	24	0.64	210	0.53
0.2666	2.72	26	0.64	220	0.53
0.2833	2.67	28	0.63	230	0.53
0.3000	2.62	30	0.63	240	0.53
0.3166	2.56	32	0.63	250	0.53
0.3333	2.51	34	0.62	260	0.53
0.4167	2.24	36	0.62	270	0.52
0.5000	2.02	38	0.61	280	0.53
0.5833	1.85	40	0.61	290	0.52
0.6667	1.70	42	0.61	300	0.51
0.7500	1.56	44	0.61	310	0.53
0.8333	1.45	46	0.61	320	0.53
0.9167	1.35	48	0.60	330	0.51
1.0000	1.27	50	0.60	340	0.51
1.0833	1.20	52	0.60	350	0.52
1.1667	1.15	54	0.60	360	0.51
1.2500	1.10	56	0.60	370	0.51
1.3333	1.06	58	0.60	380	0.51
1.4166	1.03	60	0.59	390	0.51
1.5000	0.99	62	0.59	400	0.51
1.5833	0.96	64	0.59	410	0.51
1.6667	0.94	66	0.59	420	0.48
1.7500	0.92	68	0.59	430	0.49
1.8333	0.91	70	0.58	440	0.49
1.9167	0.89	72	0.58	450	0.49
		74	0.58	460	0.49

Observation well recovery test

Time (minutes)	Drawdown (ft.)	Time (minutes)	Drawdown (ft.)	Time (minutes)	Drawdown (ft.)
0.0000	0.24	2.0	0.23	76	0.19
0.0033	0.25	2.5	0.23	78	0.19
0.0066	0.24	3.0	0.23	80	0.19
0.0099	0.24	3.5	0.23	82	0.19
0.0133	0.25	4.0	0.23	84	0.19
0.0166	0.24	4.5	0.23	86	0.19
0.0200	0.24	5.0	0.23	88	0.19
0.0233	0.25	5.5	0.22	90	0.19
0.0266	0.24	6.0	0.23	92	0.19
0.0300	0.24	6.5	0.23	94	0.19
0.0333	0.25	7.0	0.23	96	0.18
0.0500	0.24	7.5	0.23	98	0.18
0.0666	0.24	8.0	0.23	100	0.18
0.0833	0.24	8.5	0.23	110	0.18
0.1000	0.24	9.0	0.23	120	0.17
0.1166	0.24	9.5	0.23	130	0.17
0.1333	0.24	10	0.23	140	0.17
0.1500	0.24	12	0.23	150	0.14
0.1666	0.24	14	0.23	160	0.13
0.1833	0.23	16	0.22	170	0.13
0.2000	0.23	18	0.22	180	0.13
0.2166	0.24	20	0.22	190	0.14
0.2333	0.24	22	0.22	200	0.13
0.2500	0.24	24	0.22	210	0.12
0.2666	0.23	26	0.22	220	0.12
0.2833	0.24	28	0.22	230	0.12
0.3000	0.24	30	0.21	240	0.12
0.3166	0.23	32	0.21	250	0.12
0.3333	0.24	34	0.2	260	0.13
0.4167	0.23	36	0.21	270	0.12
0.5000	0.23	38	0.2	280	0.15
0.5833	0.23	40	0.2	290	0.12
0.6667	0.23	42	0.2	300	0.11
0.7500	0.23	44	0.2	310	0.14
0.8333	0.23	46	0.2	320	0.14
0.9167	0.23	48	0.2	330	0.1
1.0000	0.23	50	0.2	340	0.1
1.0833	0.23	52	0.2	350	0.11
1.1667	0.23	54	0.2	360	0.12
1.2500	0.23	56	0.2	370	0.11
1.3333	0.23	58	0.2	380	0.11
1.4166	0.23	60	0.19	390	0.11
1.5000	0.23	62	0.2	400	0.12
1.5833	0.23	64	0.2	410	0.12
1.6667	0.23	66	0.2	420	0.09
1.7500	0.23	68	0.2	430	0.11
1.8333	0.23	70	0.19	440	0.11
1.9167	0.23	72	0.19	450	0.11
		74	0.19	460	0.1

ATTACHMENT D

Hand Monitored Water-Level Data and Hydrographs of the
Hand-Measured Water-Level Data

RADIAN CORPORATION

AQUIFER TEST DATA

Owner CARSWELL Address CRSWL AFB County ____ State TX

Date 21 June 1990 Measured by Steve Fain, Scott Blount

Well No. LF04-02 Distance from pumping well ____ Type of test Pumping Test No. ____

Measuring equipment Hand Monitored w/ E-line

Time Data	Water Level Data	Discharge Data
Pump on: Date 6/21 Time 0745 (t)	Static water level ____	How Q measured ____
Pump off: Date 6/22 Time 0347 (t')	Measuring point ____	Depth of pump/air line ____
Duration of aquifer test:	Elevation of measuring point ____	Previous pumping? Yes ____ No ____
Pumping 1202 Recovery 460		Duration ____ End ____

Date	Clock Time	Time Since Pump On	Water Level	Remarks	Date	Clock Time	Time Since Pump On	Water Level	Remarks
6/21	0704	—	26.27						
	1044	179	26.35						
	1325	340	26.36						
	1705	560	26.40						
	2012	747	26.41						
	2220	875	26.44						
6/22	2419	994	26.44						
	0239	1134	26.45						
	1215	1710	26.32	recovery					

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AQUIFER TEST DATA

Owner CARSWELL Address CRSWL AFB County ______ State TX

Date 21 June 1990 Measured by Steve Fain, Scott Blount

Well No. LF04-4D Distance from pumping well ______ Type of test Pumping Test No. ______

Measuring equipment Hand measured with E-line

Time Data	Water Level Data	Discharge Data
Pump on: Date 6/21 Time 0745 (t)	Static water level ______	How Q measured ______
Pump off: Date 6/22 Time 0347 (t')	Measuring point ______	Depth of pump/air line ______
Duration of aquifer test:	Elevation of measuring point ______	Previous pumping? Yes ______ No ______
Pumping 1202 Recovery 460		Duration ______ End ______

Date	Clock Time	Time Since Pump On	Water Level	Remarks	Date	Clock Time	Time Since Pump On	Water Level	Remarks
6/21	0645	—	18.13						
	0900	75	18.13						
	1257	312	18.13						
	1415	390	18.12						
	1545	480	18.12						
	1645	540	18.11						
	1954	729	18.13						
	2203	858	18.15						
	2359	974	18.16						
6/22	0214	1109	18.15						
	1150	1685	18.17						

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AQUIFER TEST DATA

Owner CARSWELL Address CRSWL AFB County ______ State TX

Date 21 June 1990 Measured by Steve Fain, Scott Blount

Well No. LF04-4E Distance from pumping well ______ Type of test Pumping Test No. ______

Measuring equipment Hand measured with E-line

Time Data	Water Level Data	Discharge Data
Pump on: Date 6-21 Time 0745 (t)	Static water level ______	How Q measured ______
Pump off: Date 6-22 Time 0347 (t')	Measuring point ______	Depth of pump/air line ______
Duration of aquifer test:	Elevation of measuring point ______	Previous pumping? Yes ____ No ____
Pumping 1202 Recovery 460		Duration ______ End ______

Date	Clock Time	Time Since Pump On	Water Level	Remarks	Date	Clock Time	Time Since Pump On	Water Level	Remarks
6/21	0642	—	21.40			1735	590	21.45	
	0745	—	—	Start Test		1805	620	21.46	
	0800	15	21.40			1830	645	21.46	
	0815	30	21.41			1905	680	21.46	
	0830	45	21.41			1955	730	21.46	
	0845	60	21.41			2059	794	21.46	
	0900	75	21.41			2200	855	21.48	
	0930	105	21.41			2357	972	21.49	
	1000	135	21.41			0211	1106	21.49	
	1030	165	21.42			0339	1194	21.49	
	1100	195	21.42			1147	1682	21.49	recovery
	1130	225	21.42						
	1200	255	21.43						
	1230	285	21.43						
	1255	310	21.44						
	1330	345	21.44						
	1405	380	21.44						
	1435	410	21.44						
	1510	445	21.45						
	1540	475	21.45						
	1616	511	21.45						
	1640	535	21.45						
	1710	565	21.45						

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RADIAN CORPORATION

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AQUIFER TEST DATA

Owner CARSWELL Address CRSWL AFB County ______ State TX

Date 21 June 1990 Measured by Steve Fain, Scott Blount

Well No. LF04-4F Distance from pumping well ______ Type of test Pumping Test No. ______

Measuring equipment Hand measured with E-line

Time Data	Water Level Data	Discharge Data
Pump on: Date 6-21 Time 0745 (t)	Static water level ______	How Q measured ______
Pump off: Date 6-22 Time 0347 (t')	Measuring point ______	Depth of pump/air line ______
Duration of aquifer test:	Elevation of measuring point ______	Previous pumping? Yes ______ No ______
Pumping 1202 Recovery 460		Duration ______ End ______

Date	Clock Time	Time Since Pump On	Water Level	Remarks	Date	Clock Time	Time Since Pump On	Water Level	Remarks
6/21	0700	—	27.03						
	0909	84	27.03						
	1314	329	27.02						
	1700	555	27.01						
	2009	864	27.02						
	2217	872	27.04						
	2416	991	27.06						
	0232	1127	2707						
	—	—	27.07						

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AQUIFER TEST DATA

Owner Carswell Address ______ County ______ State TX

Date 21 June 1990 Measured by Steve Fain, Scott Blount

Well No. LF04-4G Distance from pumping well ______ Type of test Pumping Test Test No. ______

Measuring equipment Hand-measured with E-line

Time Data	Water Level Data	Discharge Data
Pump on: Date 6/21 Time 0745 (t)	Static water level ______	How Q measured ______
Pump off: Date 6/22 Time 0347 (t')	Measuring point ______	Depth of pump/air line ______
Duration of aquifer test:	Elevation of measuring point ______	Previous pumping? Yes ______ No ______
Pumping 1202 Recovery 460		Duration ______ End ______

Date	Clock Time	Time Since Pump On	Water Level	Remarks	Date	Clock Time	Time Since Pump On	Water Level	Remarks
6/21	0653	—	23.76						
	1304	319	23.74						
	1650	545	23.74						
	2001	736	23.74						
	2209	864	23.74						
6/22	2406	981	23.77						
	0222	1117	23.78						
	1158	1693	23.78	recovery					

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RADIAN CORPORATION

AQUIFER TEST DATA

Owner CARSWELL Address CRSWL AFB County ______ State TX

Date 21 June 1990 Measured by Steve Fain, Scott Blount

Well No. LF04-4H Distance from pumping well ______ Type of test Pumping Test Test No. ______

Measuring equipment Hand Measured with E-line

Time Data	Water Level Data	Discharge Data
Pump on: Date 6-21 Time 0745 (t)	Static water level ______	How Q measured ______
Pump off: Date 6-22 Time 0347 (t')	Measuring point ______	Depth of pump/air line ______
Duration of aquifer test:	Elevation of measuring point ______	Previous pumping? Yes ______ No ______
Pumping 1202 Recovery 460		Duration ______ End ______

Date	Clock Time	Time Since Pump On	Water Level	Remarks	Date	Clock Time	Time Since Pump On	Water Level	Remarks
6/21	0656	—	17.19						
	1300	315	17.15	(watering green					
	1645	540	17.16	adjacent to well)					
	1958	733	17.14						
	2207	862	17.17						
6/22	2403	978	17.19						
	0219	1114	17.19						
	1154	1689	17.18	recovery					

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RADIAN CORPORATION

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AQUIFER TEST DATA

Owner CARSWELL Address CRSWL County ______ State TX

Date 21 June 1990 Measured by Steve Fain, Scott Blount

Well No. 10B Distance from pumping well ______ Type of test Pumping Test No. ______

Measuring equipment Hand Measured w/ E line

Time Data	Water Level Data	Discharge Data
Pump on: Date 6-21 Time 0745 (t)	Static water level ______	How Q measured ______
Pump off: Date 6-22 Time 0347 (t')	Measuring point ______	Depth of pump/air line ______
Duration of aquifer test:	Elevation of measuring point ______	Previous pumping? Yes ______ No ______
Pumping 1202 Recovery 460		Duration ______ End ______

Date	Clock Time	Time Since Pump On	Water Level	Remarks	Date	Clock Time	Time Since Pump On	Water Level	Remarks
6/21	0658	—	25.68						
	1311	326	25.67						
	1657	552	25.67						
	2006	741	25.67						
	2215	870	25.68						
	2413	988	25.70						
	0229	1124	25.71						
	1206	1701	25.71	recovery					

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RADIAN CORPORATION

AQUIFER TEST DATA

Owner CARSWELL Address CRSWL AFB County ______ State TX

Date 6-21-90 Measured by Steve Fain, Scott Blount

Well No. LF05-5F Distance from pumping well ______ Type of test Pumping Test No. ______

Measuring equipment Hand Measured w/ E-line

Time Data	Water Level Data	Discharge Data
Pump on: Date 6-21 Time 0745 (t)	Static water level ______	How Q measured ______
Pump off: Date 6-22 Time 1347 (t')	Measuring point ______	Depth of pump/air line ______
Duration of aquifer test:	Elevation of measuring point ______	Previous pumping? Yes ______ No ______
Pumping 1202 Recovery 460		Duration ______ End ______

Date	Clock Time	Time Since Pump On	Water Level	Remarks	Date	Clock Time	Time Since Pump On	Water Level	Remarks
6-21	0655	—	21.90						
	1307	322	21.89						
	1655	550	21.89						
	2003	738	21.88						
	2213	808	21.90						
	2410	985	21.92						
	0225	1120	21.92						
	1202	1697	21.93	recovery					

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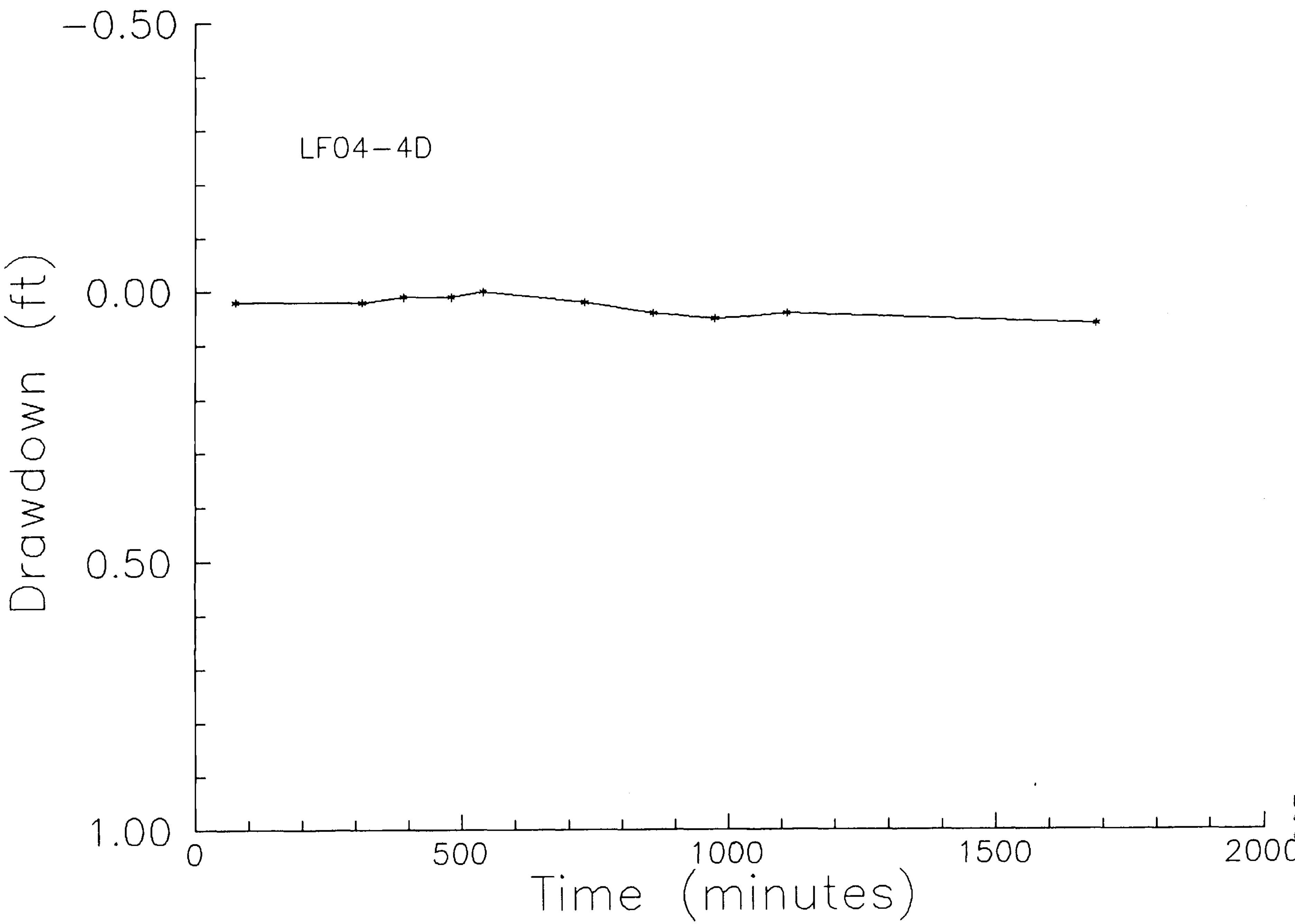
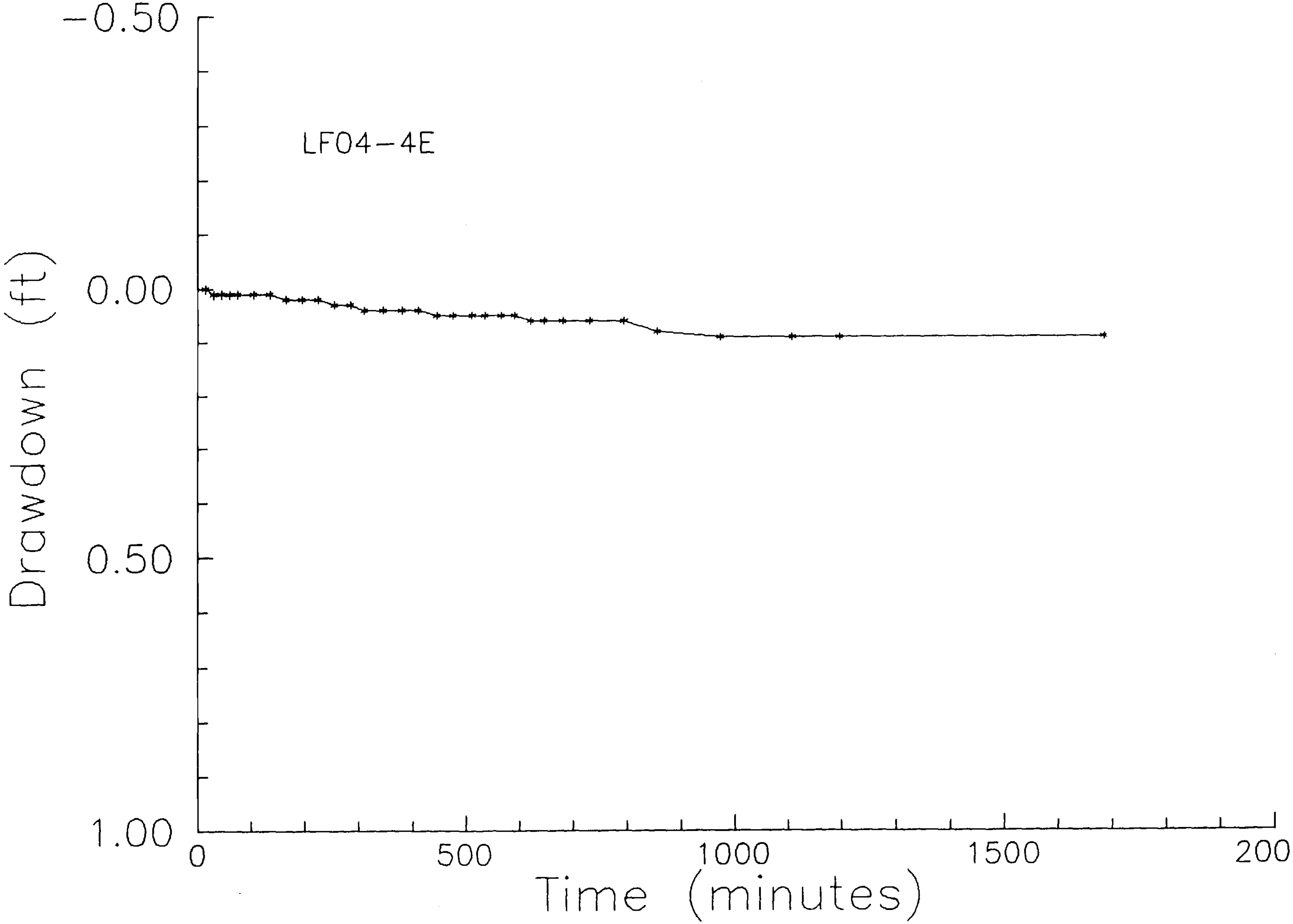


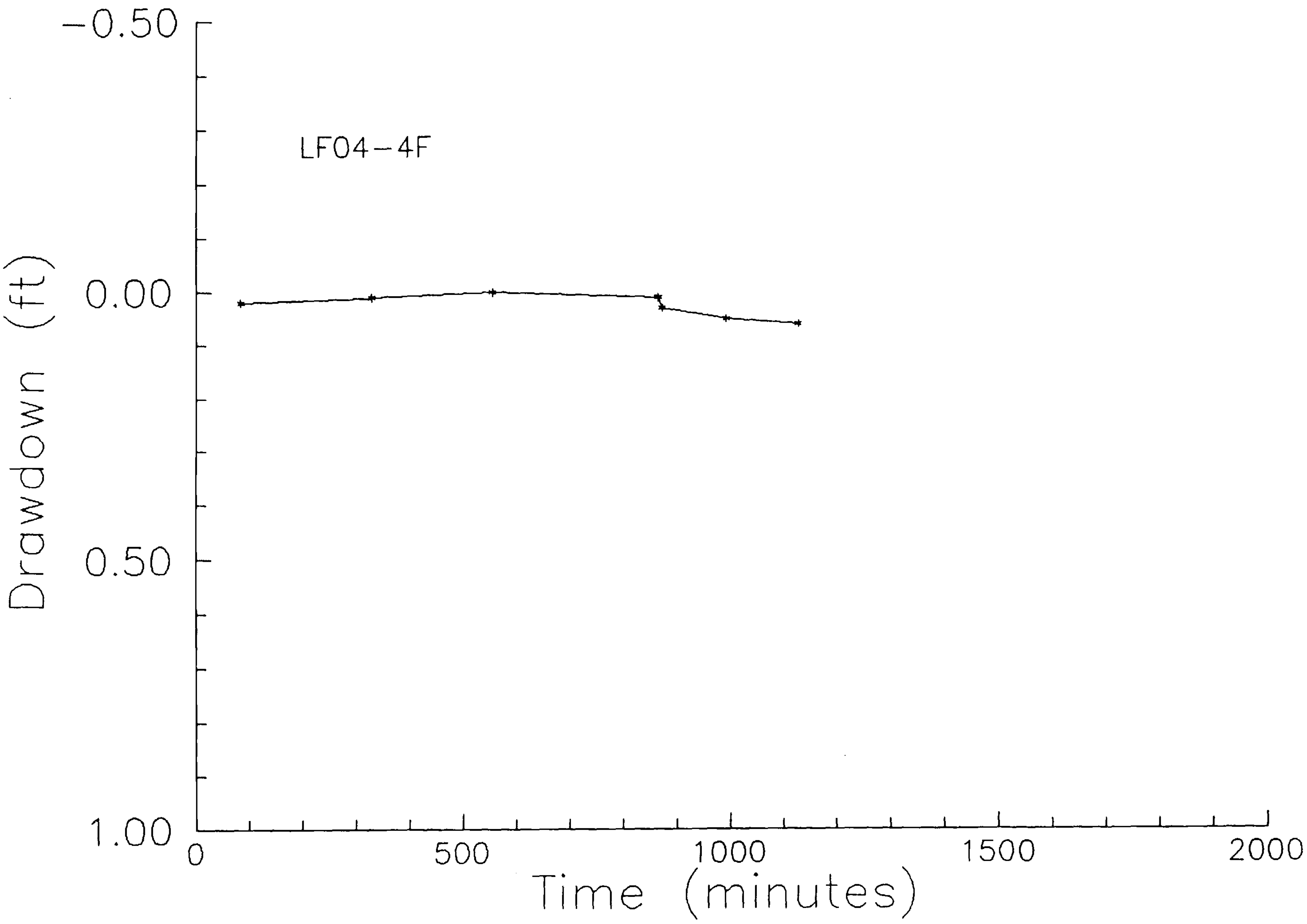
LF04-4D
Drawdown (ft)
-0.50
0.00
0.50
1.00
Time (minutes)
0
500
1000
1500
2000

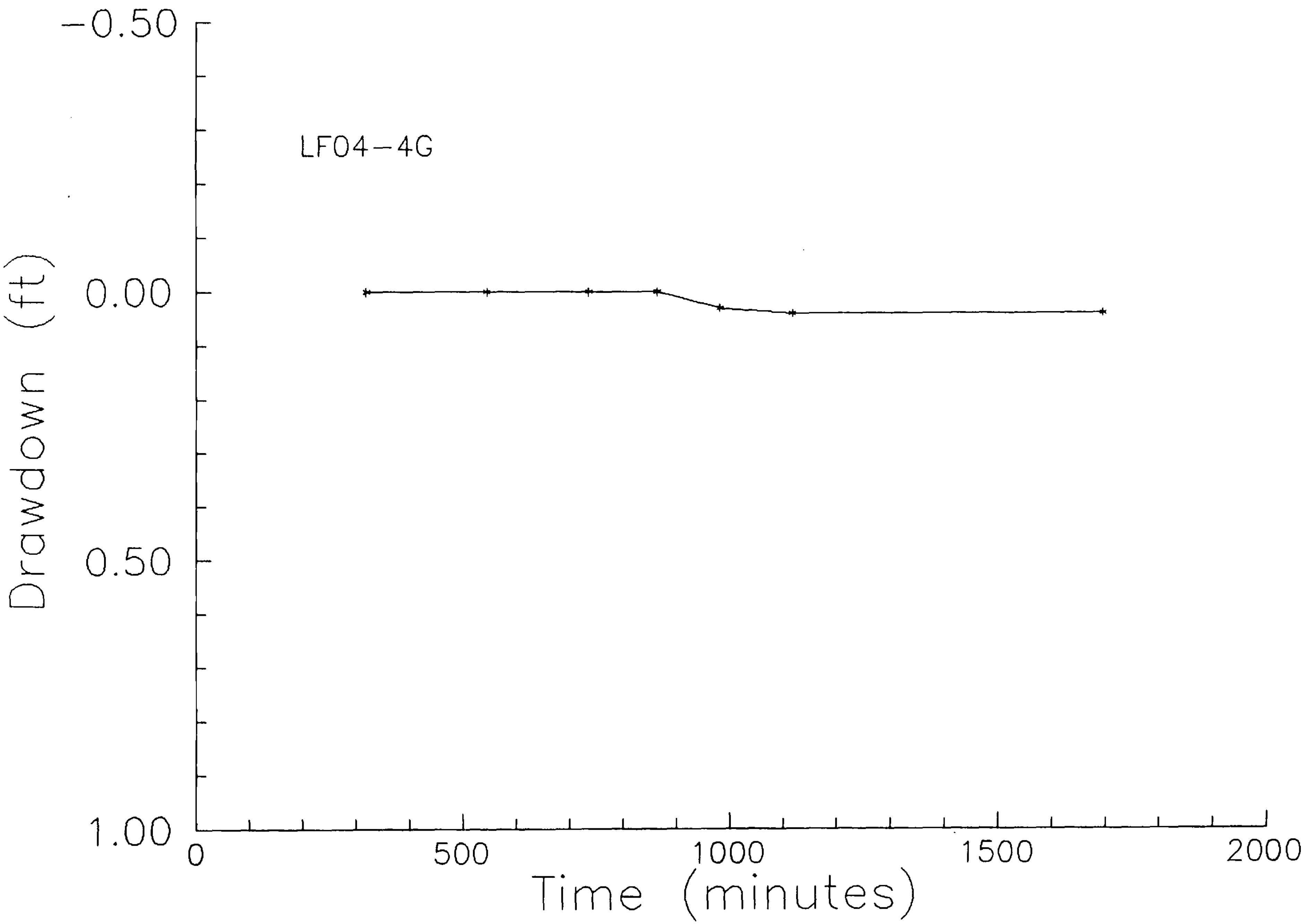
73 409



LF04-4E
Drawdown (ft)
-0.50
0.00
0.50
1.00
0
500
1000
1500
2000
Time (minutes)

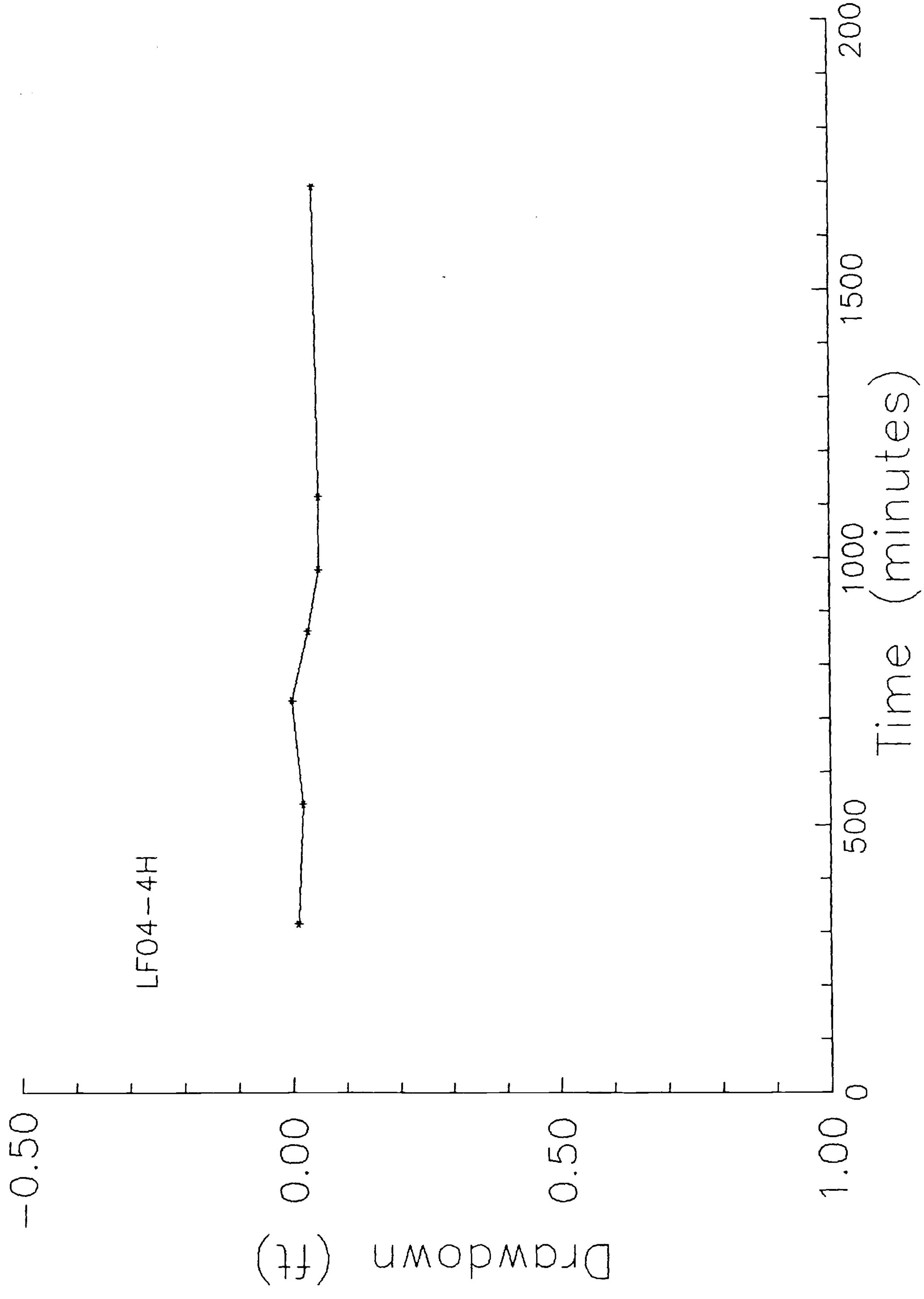
73 416


LF04-4F
Drawdown (ft)
-0.50
0.00
0.50
1.00
Time (minutes)
0
500
1000
1500
2000

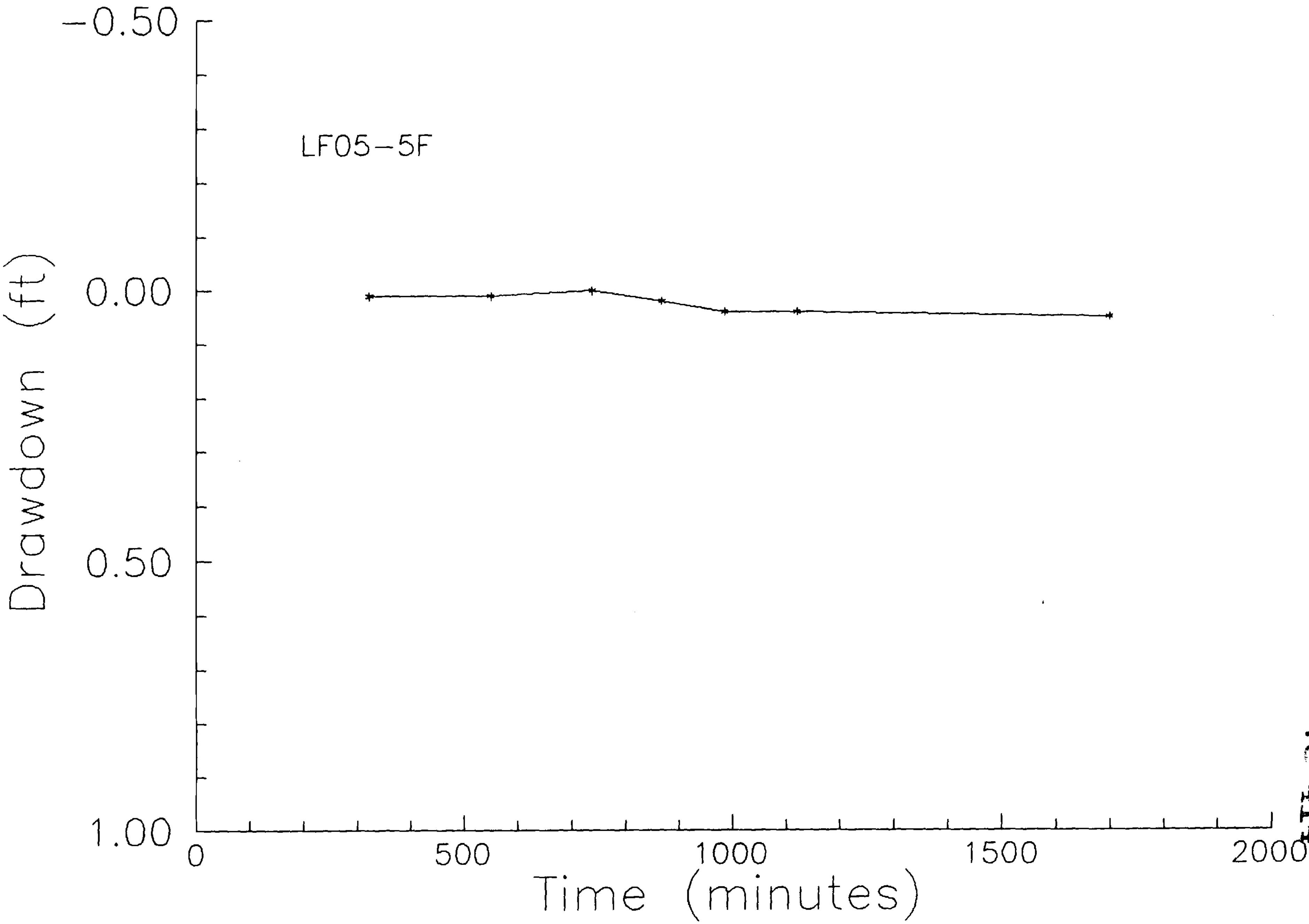

LF04-4G
-0.50
0.00
0.50
1.00
Drawdown (ft)
0
500
1000
1500
2000
Time (minutes)

73 412

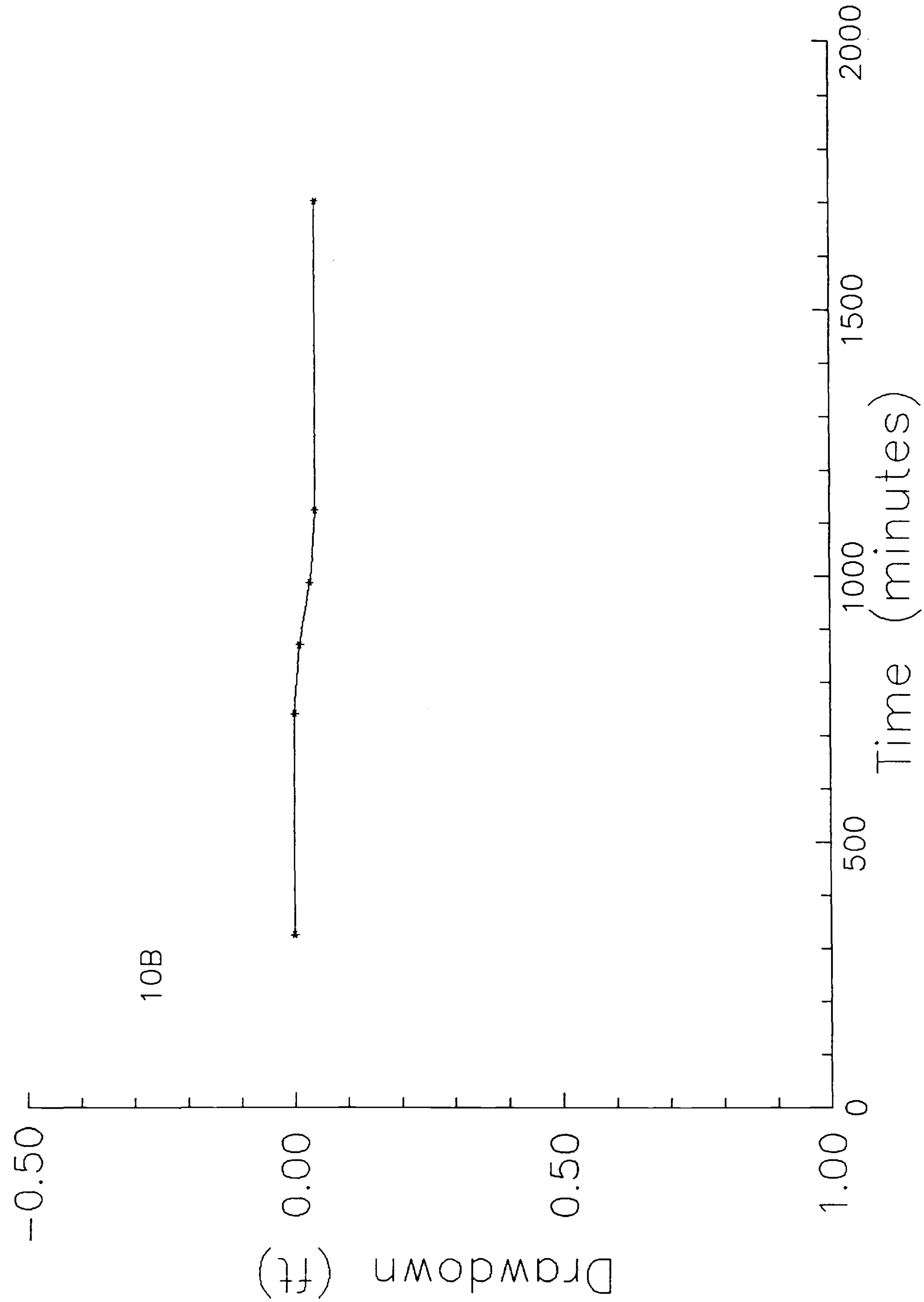
73 443


LF04-4H
Time (minutes)
0
500
1000
1500
2000
Drawdown (ft)
-0.50
0.00
0.50
1.00

73 414

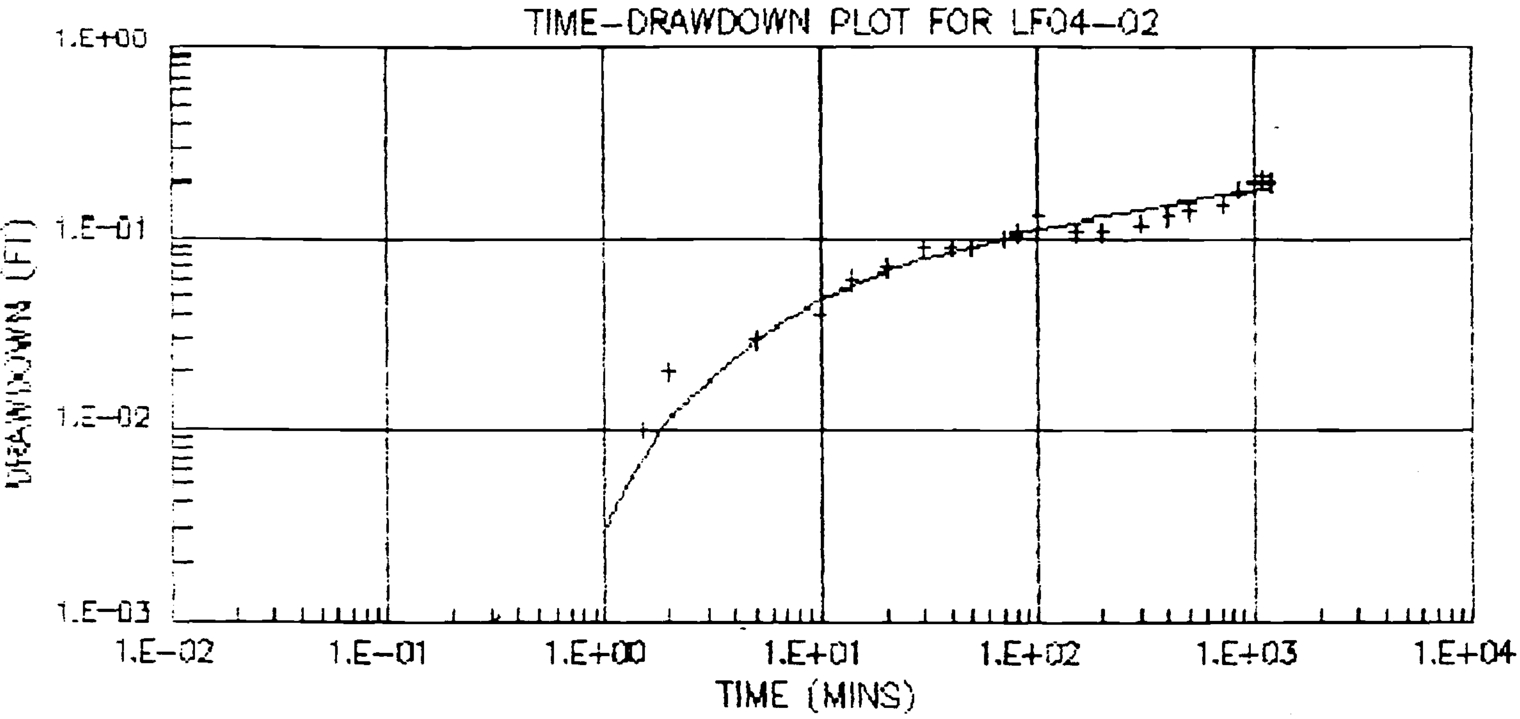

LF05-5F
-0.50
0.00
0.50
1.00
Drawdown (ft)
0
500
1000
1500
2000
Time (minutes)

73 415


10B
Time (minutes)
0
500
1000
1500
2000
Drawdown (ft)
-0.50
0.00
0.50
1.00

ATTACHMENT E

WHIP™ Plots Used in Analysis
of Pump and Recovery Tests

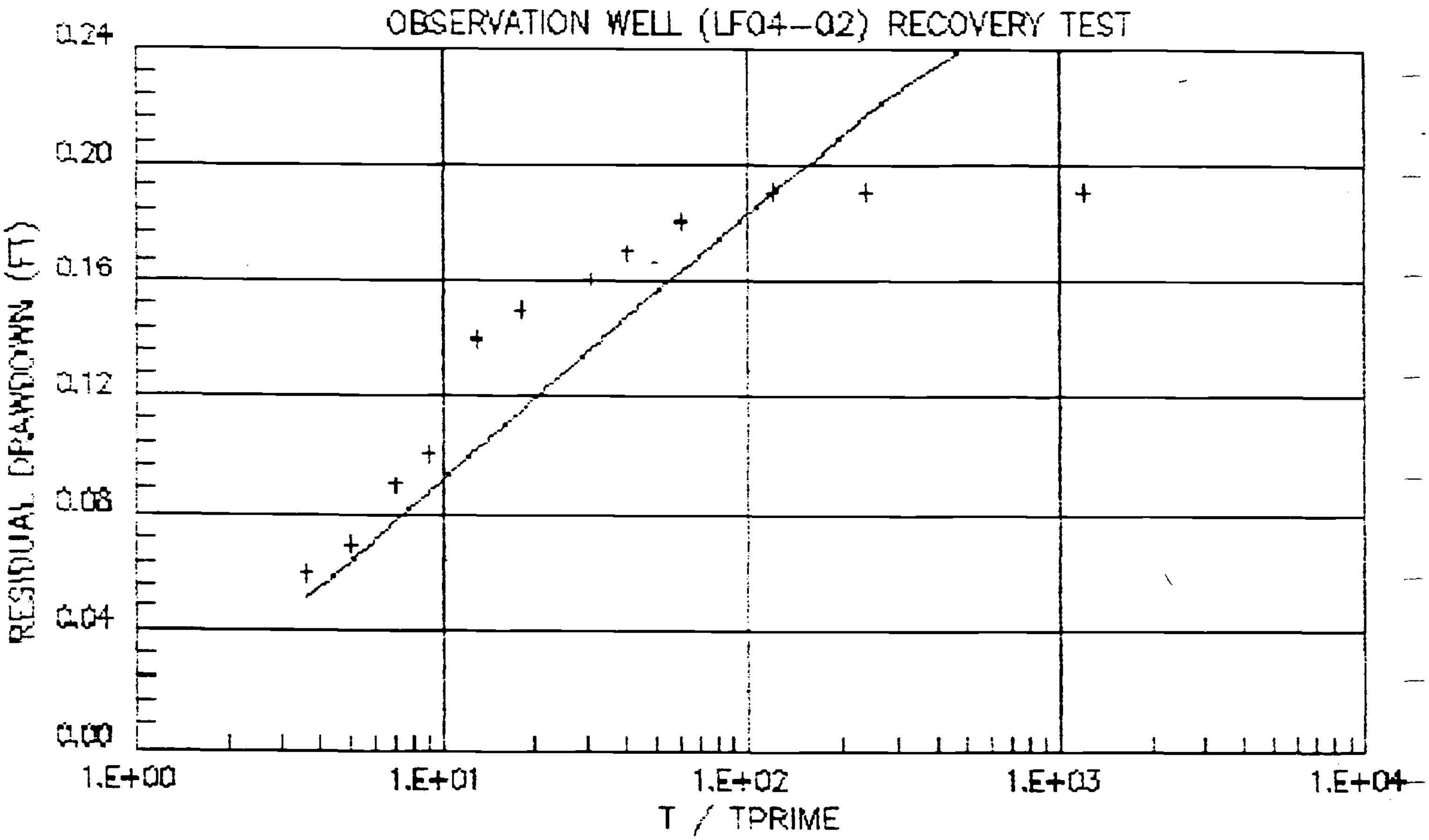


Variables

Saturated thickness = 11.7 ft
Maximum drawdown (pumping well) = 3.5 ft
r = 50 ft
Q = 18.3 gpm
Pump well radius = 0.25 ft
Effective casing radius = 0.7 ft

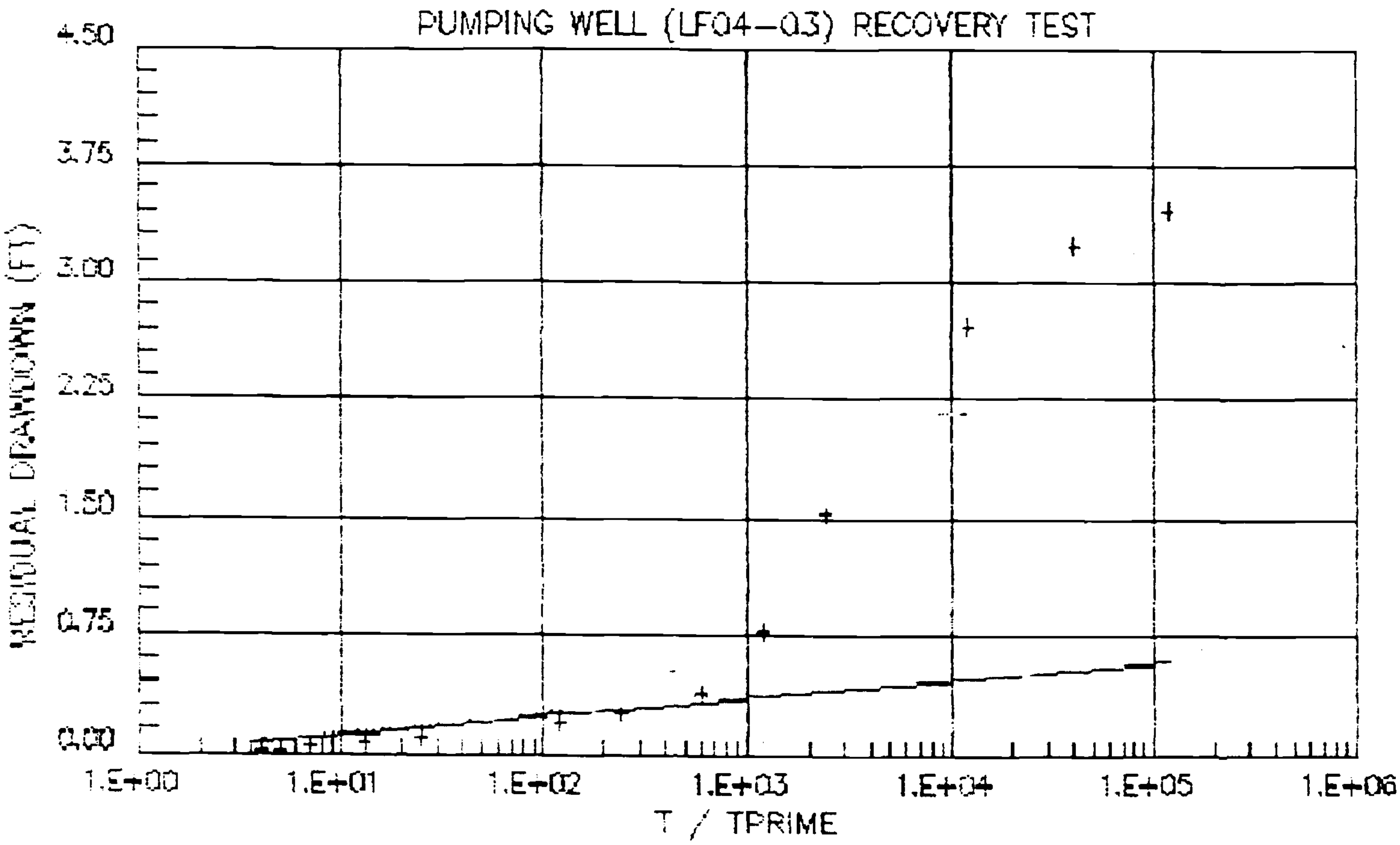
Results

Transmissivity = 9771 ft^2/day
Storage coefficient = 1.2×10^{-2}
(Results have Dupuit correction applied and have been optimized with seven iterations by the Levenberg-Marquardt Minimization Algorithm).



Results

Transmissivity = 8260 ft^2/day
(Result has been optimized with seven iterations by the Levenberg-Marquardt Minimization Algorithm).



Windowed data (2,100) on T/TPrime plot used in analysis.

<u>Results</u>

Transmissivity = 9501 ft^2/day
(Result has been optimized with seven iterations by the Levenberg-Marquardt Minimization Algorithm).

APPENDIX G

DPM Evaluation Worksheet for the Flightline Area

Site identification: Flightline Area (Sites LF04, LF05, WP07 and FT09)

SURFACE WATER PATHWAYS

Observed releases	Score (circle one)	Multiplier	Product (score x mult.)	Max. score
1. Have contaminants been detected in surface water? If yes, assign score of 100 and proceed to item 10. If no, assign score of 0 and proceed to item 2.	0 100	1	100	100
Pathway characteristics				
2. Distance to nearest surface water	0 1 2 3	4		12
3. Net precipitation	0 1 2 3	1		3
4. Surface erosion potential	0 1 2 3	4		12
5. Rainfall intensity	0 1 2 3	4		12
6. Surface permeability	0 1 2 3	3		9
7. Sum of items 2 through 6				48
8. Normalized score (multiply item 7 x 100/48)				
9. Flooding potential	0 1 2 3	8		24
10. Adjusted pathways score If item 1 is 100, enter 100. If item 1 is 0, enter sum of items 8 and 9. If sum exceeds 100, enter 100.			100	
11. Waste containment effectiveness factor (Table 2)			1.0	
12. Final score for surface water pathways (multiply item 10 x item 11)			100	

COMMENTS ON SURFACE WATER PATHWAYS

Known surface water contamination

Site identification: Flightline Area (Sites LF04, LF05, WP07 and FT09)

GROUNDWATER PATHWAYS

	Score (circle one)	Multiplier	Product (score x mult.)	Max. score
Observed releases				
13. Have contaminants been detected in groundwater? If yes, assign score of 100 and proceed to item 20. If no, assign score of 0 and proceed to item 14.	0 100	1	100	100
Pathway characteristics				
14. Depth to seasonal high groundwater from base of waste or contaminated zone	0 1 2 3	9		27
15. Permeability of the unsaturated zone	0 1 2 3	5		15
16. Infiltration potential	0 1 2 3	5		15
17. Sum of items 14 through 16				57
18. Normalized score (multiply item 17 x 100/57)				
19. Potential for discrete features in the unsaturated zone to "short-circuit" the pathway to the water table	0 1 2 3	5		15
20. Adjusted pathways score. If item 13 is 100, enter 100. If item 13 is 0, enter sum of items 18 and 19. If sum exceeds 100, enter 100.			100	
21. Waste containment effectiveness factor (Table 5)			1.0	
22. Final score for groundwater pathways (multiply item 20 x item 21)			100	

COMMENTS ON GROUNDWATER PATHWAYS

Known ground-water contamination

Site identification: Flightline Area (Sites LF04, LF05, WP07 and FT09)

CONTAMINANT HAZARD -- SURFACE WATER

If contaminants have been detected in surface water (score of 100 in item 1), complete items 23 through 28. If contaminants have not been detected (score of 0 in item 1), complete items 29 through 32. Attach Hazard Worksheet or list of contaminants, as appropriate.

		Score (circle one)	Result	Logarithm (base 10)
23.	Sum of human health hazard quotients (from column 10 of Hazard Worksheet)		2.9×10^7	7.5
24.	Human health hazard score	0 1 2 4 6		
25.	Normalized human health hazard score (multiply item 24 x 100/6)		100	
26.	Sum of ecological hazard quotients (enter the larger of the sums of column 11 or 12 of Hazard Worksheet)		9.97	1.0
27.	Ecological hazard score	0 1 2 3 4 5 6		
28.	Normalized ecological hazard score (multiply item 27 x 100/6)		50.0	
29.	Maximum human health hazard index	0 1 2 3 4 5 6 7 8 9	Contaminant: ______	
30.	Normalized human health hazard score (multiply item 29 x 100/9)		______	
31.	Maximum ecological hazard index	0 1 2 4 6	Contaminant: ______	
32.	Normalized ecological hazard score (multiply item 31 x 100/6)		______	

CONTAMINANT HAZARD -- GROUNDWATER

If contaminants have been detected in groundwater (score of 100 in item 13), complete items 33 through 38. If contaminants have not been detected (score of 0 in item 13), complete items 39 through 42. Attach Hazard Worksheet or list of contaminants, as appropriate.

		Score	Result	Logarithm
33.	Sum of human health hazard quotients (from column 10 of Hazard Worksheet)		1.2×10^{11}	11.1
34.	Human health hazard score	0 1 2 4 6		
35.	Normalized human health hazard score (multiply item 34 x 100/6)		100	
36.	Sum of ecological hazard quotients (enter the larger of the sums of column 11 or 12 of Hazard Worksheet)		293.9	2.5
37.	Ecological hazard score	0 1 2 3 4 5 6		
38.	Normalized ecological hazard score (multiply item 37 x 100/6)		83.3	
39.	Maximum human health hazard index	0 1 2 3 4 5 6 7 8 9	Contaminant: ______	
40.	Normalized human health hazard score (multiply item 39 x 100/9)		______	
41.	Maximum ecological hazard index	0 1 2 4 6	Contaminant: ______	
42.	Normalized ecological hazard score (multiply item 41 x 100/6)		______	

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Site identification: Flightline Area (Sites LF04, LF05, WP07 and FT09)

HUMAN HEALTH RECEPTORS -- SURFACE WATER PATHWAY

		Score (circle one)	Multiplier	Product (score x mult.)	Max. score
43.	Population that obtains drinking water from potentially affected surface water body(ies) within 3 miles (4.8 km) downstream	0 1 2 3	3	9	9
44.	Water use of nearest surface water body(ies)	0 1 2 3	3	9	9
45.	Population within 1000 ft (305 m) of the site	0 1 2 3	1	3	3
46.	Distance to the nearest installation boundary	0 1 2 3	1	3	3
47.	Land use and/or zoning within 1 mile (1.6 km) of the site	0 1 2 3	1	3	3
48.	Sum of items 43 through 47			27	27
49.	Final score for human health receptors on surface water pathways (multiply item 48 x 100/27)		100		

ECOLOGICAL RECEPTORS -- SURFACE WATER PATHWAYS

		Score (circle one)	Multiplier	Product (score x mult.)	Max. score
50.	Importance/sensitivity of biota/habitats in potentially affected surface water bodies nearest the site	0 1 2 3	5	10	15
51.	Presence of "critical environments" within 1 mile (1.6 km) of the site	0 3	1	0	3
52.	Sum of items 50 and 51			10	18
53.	Final score for ecological receptors on surface water pathways (multiply item 52 x 100/18)			55.6	

COMMENTS ON SURFACE WATER RECEPTORS

Site identification: Flightline Area (Sites LF04, LF05, WP07 and FT09)

HUMAN HEALTH RECEPTORS -- GROUNDWATER PATHWAY

		Score (circle one)	Multiplier	Product (score x mult.)	Max. score
54.	Estimated mean groundwater travel time from current waste location to nearest downgradient water supply well(s)	0 1 2 3	9	0	27
55.	Estimated mean groundwater travel time from current waste location to any downgradient surface water body that supplies water for domestic use or for food chain agriculture	0 1 2 3	5	10	15
56.	Groundwater use of the uppermost aquifer	0 1 2 3	4	8	12
57.	Population potentially at risk from groundwater contamination	0 6 9 12 18 24 27 36	1	27	36
58.	Population within 1000 ft (305 m) of the site	0 1 2 3	1	3	3
59.	Distance to the nearest installation boundary	0 1 2 3	1	3	3
60.	Sum of items 54 through 59			51	96
61.	Final score for human health receptors on groundwater pathways (multiply item 60 x 100/96)			53.1	

ECOLOGICAL RECEPTORS -- GROUNDWATER PATHWAYS

		Score (circle one)	Multiplier	Product (score x mult.)	Max. score
62.	Estimated mean groundwater travel time from current waste location to any downgradient habitat or natural area	0 1 2 3	3	6	9
63.	Importance/sensitivity of downgradient biota/habitats that are confirmed or suspected groundwater discharge points	0 1 2 3	3	6	9
64.	Presence of "critical environments" within 1 mile (1.6 km) of the site	0 3	1	0	3
65.	Sum of items 62 through 64			12	21
66.	Final score for ecological receptors on groundwater pathways (multiply item 65 x 100/21)			57.1	

COMMENTS ON GROUNDWATER RECEPTORS (attach additional pages if needed)

54. No downgradient wells.

55. Travel time 0.2 ft/day. 1,000 ft to surface water. 13.9 days.

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Site identification: Flightline Area (Sites LF04, LF05, WP07 and FT09)

SCORING SUMMARY SHEET

		Pathways score		Contaminant hazard score		Receptors score		Overall score
67.	Surface water/human health scores	(100 (item 12)	x	100 (item 25/30)	x	100 (item 49)	) /10,000 =	100
68.	Surface water/ecological scores	(100 (item 12)	x	50 (item 28/32)	x	55.6 (item 53)	) /10,000 =	27.8
69.	Groundwater/human health scores	(100 (item 22)	x	100 (item 35/40)	x	53.1 (item 61)	) /10,000 =	53.1
70.	Groundwater/ecological scores	(100 (item 22)	x	83.3 (item 38/42)	x	57.1 (item 66)	) /10,000 =	47.6

OVERALL SITE SCORE:

71. $(\underset{\text{item 67}}{\underline{100}})^2 \times 5 + (\underset{\text{item 68}}{\underline{27.8}})^2 + (\underset{\text{item 69}}{\underline{53.1}})^2 \times 5 + (\underset{\text{item 70}}{\underline{47.6}})^2 = \underline{67,136.65}$

72. Overall site score $= \sqrt{\underset{\text{item 71}}{\underline{67,136.65}}}\,/\,3.464 = \underline{19,381.25}$

FLIGHT LINE AREA--GROUND WATER

CONT. NAME	CONC. (UG/L)	HEALTH BMARK	AQUATIC BMARK	TERRE BMARK	BIOACC BMARK	W INTAKE (UG/DAY)	F INTAKE (UG/DAY)	TOTAL INTAKE	HEALTH QUOTIEN	AQ HAZ QUOTIEN	TERRE HAZ QUOTIENT
TETRACHLOROETH	30000	4	5280	0	44	60000	8580	5.1E+08	1.3E+08	5.681818	0
TRICHLOROETHEN	4400000	42	45000	0	17	8800000	486200	4.28E+12	1.02E+11	97.77777	0
VINYL CHLORIDE	170000	1000	381000	0	7.2	340000	7956	2.71E+09	2705040	0.446194	0
CIS-1,2-DCE	730000	2.6	135000	2.0E+08	7.2	1460000	34164	4.99E+10	1.92E+10	5.407407	0
ARSENIC	53	0.04	360	100	280	106	96.46	10224.76	255619	0.147222	0.53
CHROMIUM	200	0.016	16	100	200	400	260	104000	6500000	12.5	2
IRON	61000	150	400	5000	100	122000	39650	4.84E+09	32248666	152.5	12.2
LEAD	90	100	34	5000	300	180	175.5	31590	315.9	2.647058	0.018
MANGANESE	5000	0.25	350	200	400	10000	13000	1.3E+08	5.2E+08	14.28571	25
MERCURY	6.2	0.4	2.4	0	63000	12.4	2538.9	31482.36	78705.9	2.583333	0
								TOTALS	1.22E+11	293.9765	39.748

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FINAL PAGE

ADMINISTRATIVE RECORD

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